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THE PLANETS AND THEIR ATMOSPHERES

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THROUGHOUT the years since primitive man first raised his eyes to the heavens and saw the evening star the planets, called by the Greeks the wandering stars, have held remarkable interest for the human mind.

Apart from their beauty, the mystery of their motions and of their changing brightness has made a constant appeal through the centuries to man's curiosity and love of discovery. After Copernicus and Galileo the knowledge of the relationship of the planets to our earth as common children of the sun, with a similar history, and the prospect of a similar fate, has continued to stir the imagination.

So it is by no means strange that the planets have figured so greatly in poetry and literature, nor even that among the absurdities of astrology we find crude expression of the permanent interest attaching to the members of our solar family.

In recent years with the growth in our knowledge of the universes of stars it is with something of the feeling of a traveler returning to his home after a long journey that we turn back from the appalling distances and loneliness of space to the narrow limits governed by our sun. In much the same way we can picture Columbus counting the ships in the harbor of Lisbon after his lonely months upon the Atlantic.

SHIFT OF INTEREST

With the progress of human thought and discovery our interest in the planets has naturally turned more and more toward their physical characteristics and constitution. The earliest great problem was that of their motions and with its solution man gained an answer to many of the questions which had so long baffled him, the mystery of Venus as a morning and an evening star, the elusive glimpses of Mercury, now on one side of the sun and now on the other, and the strange motions of the outer planets which appear to move among the stars, then stop and retrace their steps.

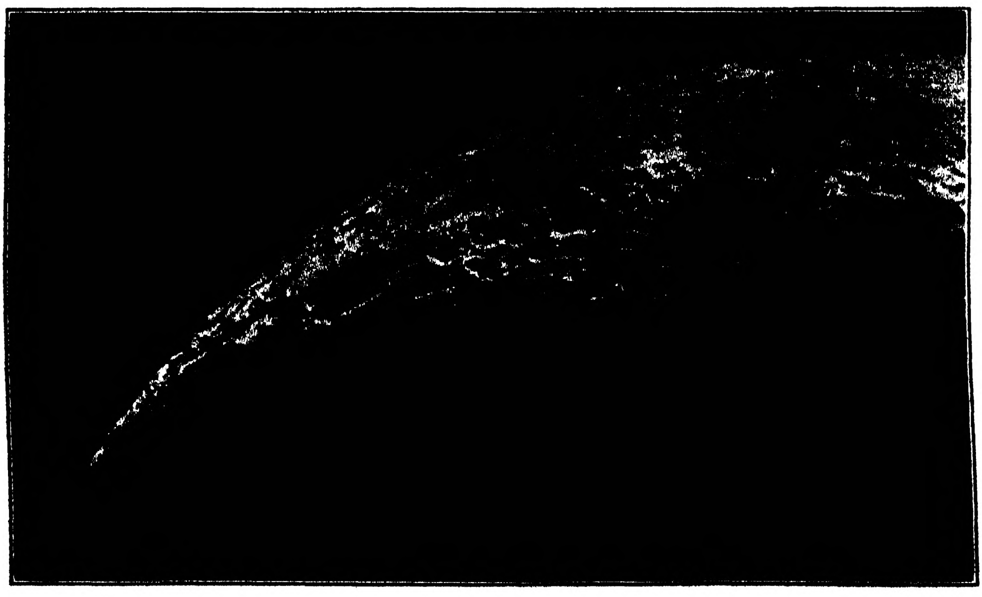
When the telescope and accurate methods of measurement were developed we rapidly gained a knowledge of their distances, their sizes, masses and forms. So our knowledge of the individual planets considered as astronomical bodies is very complete. Naturally the degree of accuracy varies with different planets. The mass of Mercury is uncertain within a considerable range, and in the case of Pluto we can do little more than form probable limits for its size and mass based upon considerations of brightness and the disturbances it produces in the motions of other planets. But in general our facts regarding the planets as a whole are very reliable.

Difficulties Affecting Study

It is quite different when we begin to consider the constitution of the planets, their atmospheres and the conditions prevailing on their surfaces. In the first place planets shine by reflected light and are not self-luminous. Hence the light we receive from a planet is simply sunlight modified to some degree by transmission through the planet's atmosphere in case such an atmosphere exists. Difficult as it is to realize, it is a much more serious problem to learn the composition of the surface of our satellite, the moon, the nearest object in the sky, than of a star the light of which may be thousands of years in reaching us.

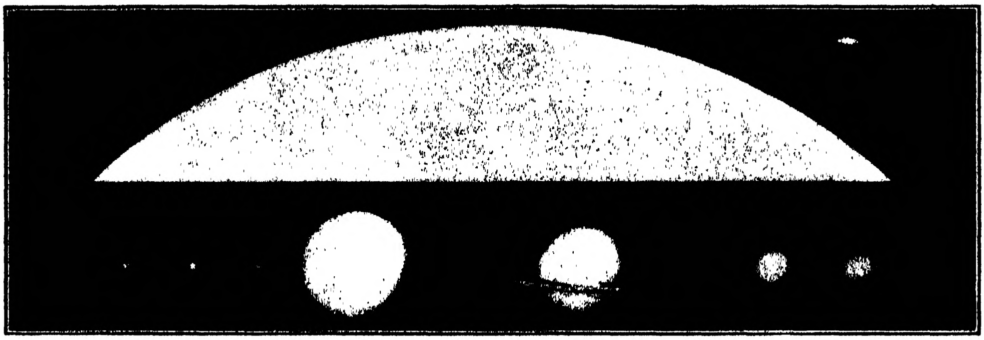
The gases of the elements composing the atmosphere of the sun or a star radiate or absorb their own characteristic light and give immediate evidence of their presence when the light is analyzed with a spectroscope, while the moon acts as a mirror and simply reflects the light it receives from the sun. In fact, almost all our knowledge of the nature of the material composing the surface of the moon is obtained through a study of the influence of reflection by different kinds of materials upon the plane of vibration of light waves, a phenomenon skilfully utilized by Dr. Wright, of the Carnegie Institution, to prove that the moon's surface can not consist of exposed rock, but must be covered by a layer of very fine sand or, more probably, volcanic or meteoric dust.

Much of our information regarding the planets must depend upon direct visual and photographic observations. Surface markings, the periods of rotation, clouds and varying features on the apparent surface, and to some extent the presence or absence of an atmosphere itself must all be studied with the telescope, and here we encounter the serious difficulty of atmospheric disturbances.



THE SOUTHERN PORTION OF THE MOON

TWENTY-SIX DAYS AFTER THE "NEW MOON" APPEARS; TAKEN WITH THE 100-INCH TELESCOPE AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY. ON THE MOON THERE IS NO WATER VAPOR NOR ANY OTHER GAS TO EQUALIZE THE SUN'S RADIATION; CONSEQUENTLY ITS TEMPERATURE UNDERGOES ENORMOUS VARIATIONS, FROM THAT OF BOILING WATER ON THE SIDE TOWARDS THE SUN TO 250° BELOW ZERO, FAHRENHEIT, ON THE DARK SIDE.



SHOWING THE RELATIVE SIZE OF THE SUN AND PLANETS
FROM A PHOTOGRAPH OF THE MODELS PREPARED BY THE MOUNT WILSON OBSERVATORY FOR THE ANNUAL EXHIBITION OF CARNEGIE INSTITUTION, HELD IN DECEMBER, 1933. *Upper*—A SEGMENT OF THE SUN IN SCALE WITH THE PLANETS. *Lower* (FROM LEFT TO RIGHT)—MERCURY, VENUS, EARTH AND THE MOON, MARS, JUPITER, SATURN, URANUS, NEPTUNE, PLUTO.

ATMOSPHERIC DISTURBANCES

When a telescope is pointed to the sky it is looking out through the entire depth of the earth's atmosphere. Each irregularity in the temperature and density of the air through which the light passes bends and twists the beam of light, and as such irregularities change very rapidly there is a continual blurring and quivering of the image. This is the familiar twinkling of the stars so often seen on a windy winter night, and in a telescope the effect is increased in proportion to its magnifying power. Such a blurring effect goes far toward obliterating the surface details and finer markings on the planets or the sun and moon, and explains why astronomers seek to locate their observatories where the air is most steady and free from disturbance, and why Percival Lowell established his observatory, primarily for the study of Mars, on an isolated plateau in central Arizona.

It also answers the question most frequently asked of astronomers whether a telescope can not be built sufficiently large to bring the moon within a few miles and Mars within a few hundreds of miles and so make even the smallest details visible. There is ample light for such observations with existing telescopes, and the magnifying power may be made as high as may be desired, but unfortunately the disturbances due to the earth's atmosphere are magnified along with the planet's disk and nothing is gained.

If the earth's atmosphere could be removed the astronomer could use a compound microscope attached to his telescope to view the moon, and the limit of magnification in the case of the planets would be set only by the resolving power of his telescope and the disturbances in the atmospheres of the planets themselves.

These difficulties affecting observations of the planets explain in part why our knowledge of their physical state is less complete than our knowledge of them as astronomical bodies. Much has been learned, however, and much more may be expected with the development of new and more sensitive instruments for measuring radiation and for studying the influence of the atmospheres and the surface materials of the planets upon the quality of the reflected light.

FACTORS GOVERNING CONDITIONS

There are three important factors which govern to a large extent physical conditions upon a planet and what we

may call its climate. The first is, of course, its distance from the sun. This determines the amount of heat and light which it receives, a quantity which varies for each unit of area as the square of the distance. Thus Neptune, which is thirty times as far away from the sun as the earth, receives only one nine-hundredth as much light and heat on equal areas of its surface.

The second factor is the length of the planet's day, its period of rotation on its axis. This regulates the amount of time during which the sun's heat falls on different portions of the surface. The more rapidly a planet rotates the more nearly uniform will be the amount of heat received by all its parts.

SHOWING THE PLANETARY ORBITS FOR 1933, IN SCALE

In this representation the orbits of the inner planets, Mercury, Venus, Earth and Mars, are too small to be readily distinguished without a handglass. The length of the arrow on the orbits of the outer planets, Jupiter, Saturn, Uranus, Neptune and Pluto, represents the distance traveled by the planet in one year.

An extreme case is that of Mercury, which is generally believed to rotate in the same period of 88 days in which it revolves about the sun. Hence the planet always turns the same face to the sun, as does the moon to the earth, and one side is intensely heated by the powerful solar radiation, while the other side never receives any sunlight and must be extremely cold.

The third consideration which bears especially upon the question of planetary atmospheres is that of the masses of the planets. We do not know definitely that all the planets originally had atmospheres, although this seems probable, but if they did several of the planets would have lost them either completely or in part because they were not massive enough to retain them.

The molecules composing the gases of an atmosphere are constantly flying about with high velocities, colliding with one another and rebounding in all directions. These velocities are highest for the lightest gases like hydrogen and helium and lower for the heavier gases like oxygen and nitrogen. Furthermore, the velocities are increased by increase of temperature. As a result, if a rapidly moving molecule in the upper part of a planet's atmosphere where collisions are infrequent is not attracted by the planet with a force sufficient to counteract its velocity of escape, it will fly off into space and be lost.

So a planet has to have a considerable mass in order to retain its atmosphere and especially to hold the lighter gases like hydrogen and helium which would be the first to escape. In the earlier stages of their history when the planets were probably much hotter the rate of escape for all gases must have been much more rapid.

Masses Compared

If we compare the results of observation with what might be expected from theory, we find remarkably good agreement. Mercury with a mass about one twentieth that of the earth has no atmosphere, while Venus with nearly the mass of the earth has an extensive atmosphere.

The earth has probably lost some of its free hydrogen but shows a small amount of helium and abundance of the heavier gases like nitrogen and oxygen. Our satellite, the moon, with one eightieth the mass of the earth, has no atmosphere, and on Mars, with one tenth the earth's mass, the atmosphere is thin and of low density.

On the other hand, the giant major planets with masses ranging from 15 times the mass of the earth, in the case of Uranus, to over 300, in the case of Jupiter, have dense and extensive atmospheres. They have doubtless retained all their original gases, including hydrogen and helium, the gravitational attraction of their great masses binding the molecules of the gases firmly to the planets.

Evidence of Atmosphere

The presence of an atmosphere around a planet is usually detected from observations of clouds and variable markings, or, as in the case of Venus, from the extension of the horns of the crescent beyond the diameter of the planet, owing to the diffuse reflection of light in the planet's atmosphere—an effect similar to our twilight.

For our knowledge of its composition we must then depend upon the spectroscope, which analyzes the light and shows what modifications the sunlight has undergone in passing through the atmosphere. These usually occur in the form of bands and lines which are due to the absorption of the cold molecules of gas and appear for the most part in the red and infra-red portions of the spectrum.

The most prominent in the earth's atmosphere are those due to oxygen, water vapor and carbon dioxide. Ozone produces a few faint lines in the yellow portion of the spectrum, but its principal bands lie in the ultra-violet and are so strong that they set a definite limit to the extent of the spectra of the sun and stars. Astrophysically this is most unfortunate, but, as Dr. Abbot and others have emphasized, life could hardly exist upon the earth if exposed directly to this highly penetrating radiation from the sun.

Since the surfaces of planets must be observed not only through their own atmospheres but through that of the earth as well, the bands and lines due to our atmosphere are always present in the spectra of the planets. There are two ways in which the effect due to the earth may be separated from that due to the planet, and the relative abundance of the gases in the two atmospheres may be determined.

The first is by comparing the intensities of the bands in the spectrum of the planet with those obtained from light transmitted through the earth's atmosphere alone. For example, the spectrum of Mars, in which the light from the sun has passed first through the planet's atmosphere to the surface, then outward from the surface toward the earth, and finally through the earth's atmosphere, is compared with the spectrum of the moon, which has no atmosphere.

If the altitude of the moon in the sky is the same as that of Mars the length of path through the earth's atmosphere is the same in both cases, and any excess of intensity in the lines of the spectrum of Mars must be ascribed to the gas in the planet's atmosphere. Allowance must, of course, be made for the double path of sunlight through the atmosphere of the planet which should increase the intensity of the planetary lines.

A second method of separating planetary lines from those of terrestrial origin depends upon the fact that the motion of a planet toward or away from the earth produces a displacement of the spectral lines. Accordingly if a time is selected when a planet is approaching or receding rapidly from the earth and the spectrum can be photographed on a sufficient scale the planetary lines will ap-

pear completely separated from those due to the earth's atmosphere. This method has marked advantages over that in which measurements are made upon the intensities of the superposed lines, but both methods have been used in the study of planetary spectra, especially those of Venus and Mars.

Measuring Temperatures

The second important means for investigating physical conditions on the planets is through direct measurements of temperature. Such methods have developed out of the remarkable improvements in the construction of sensitive heat-recording electrical instruments. Dr. Pfund and Dr. Coblentz were among the pioneers in this field, and Coblentz and Lampland, of the Lowell Observatory, made some of the first and most accurate observations of planetary temperatures.

Several different types of instruments are available, but that which has been used most extensively contains a thermocouple as the heat-sensitive element. It depends upon the fact that when the junction between certain metals is warmed an electric current is set up which may be measured with a sensitive galvanometer. For most astronomical purposes bismuth and an alloy of bismuth with a small amount of tin have been used, and the dimensions of the thermocouple as well as of the receivers, the thin strips of metal upon which the image of the planet or the star falls, are made almost incredibly small. The entire weight of some of the compensated thermocouples used by Pettit and Nicholson at Mount Wilson, including the receivers and their connections, is about one thousandth part of that of a drop of water.

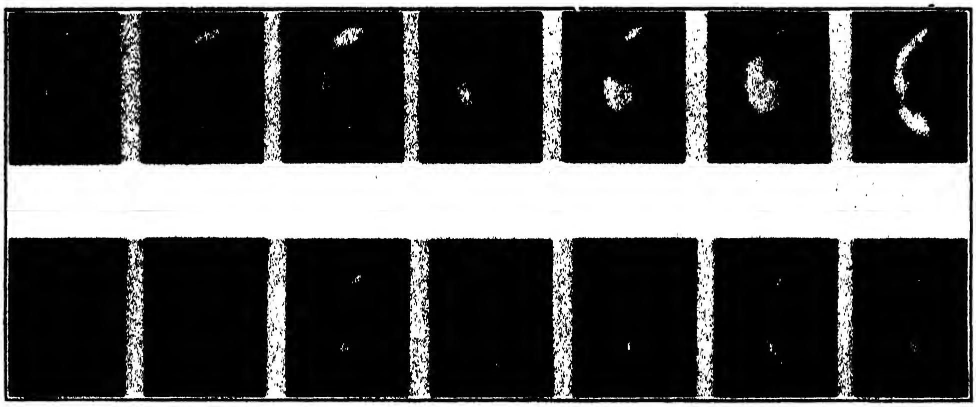
The thermocouple is placed in a high vacuum which increases its sensitiveness greatly, and during the observations the image of the star or planet is thrown alternately upon one receiver and then upon the other so that the effect of the measured heat is doubled. The receivers, which are about one fiftieth of an inch in diameter, are so small that details of planetary surfaces, such as the polar caps and the dark and bright markings on the surface of Mars, can be studied individually.

With such an instrument, a rise in temperature of the receiver of three hundred-thousandths of a degree is measured without difficulty, and the heat of stars invisible to the naked eye has been determined with the aid of the 100-inch telescope.

When a planet receives radiation from the sun a part is reflected directly away in the form of reflected sunlight and a part is absorbed and warms the planet and is re-radiated in the form of long heat waves. This radiation is that which determines the temperature of the planet. Accordingly, two sets of measures are made, one through a thin plate of glass which absorbs most of the planetary radiation and the other with the glass plate removed. In this way the amount of heat emitted by the planet itself is determined, and through application of the law connecting temperature with radiation, with due allowance for the absorption by the earth's atmosphere, the temperature of the planet is calculated.

We may now pass to a consideration of the results found for the individual planets. Beginning with Mercury, which has a mean distance from the sun only about one third that of the earth, we find a planet of small mass exposed to intense heat from the sun, and, as we have already seen, always turning the same face toward it. Both visual and spectroscopic observations agree in showing that it can have no appreciable atmosphere, a conclusion which is confirmed by its appearance when observed crossing the disk of the sun as a small black spot during one of its transits.

The temperature on the surface



FROM ULTRA-VIOLET PHOTOGRAPHS OF VENUS

TAKEN AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY. UPPER SERIES—TAKEN IN JUNE. LOWER SERIES—TAKEN IN JULY. VENUS BEARS CLOSE COMPARISON WITH THE EARTH IN MANY RESPECTS, HAVING NEARLY THE SAME SIZE AND DENSITY AND ABOUT NINE TENTHS THE SURFACE GRAVITY. IT HAS AN EXTENSIVE ATMOSPHERE, LESS DENSE THAN THAT OF THE EARTH, AND A PERMANENT LAYER OF CLOUDS WHICH PREVENTS ITS SURFACE CONDITIONS FROM BEING KNOWN. CARBON DIOXIDE GAS IN LARGE QUANTITIES IS PRESENT IN ITS UPPER ATMOSPHERE, BUT OXYGEN AND WATER VAPOR APPEAR TO BE ABSENT FROM THE REGION ABOVE THE CLOUD LEVEL FROM WHICH THE LIGHT IS REFLECTED.

turned toward the sun is extremely high, about 600° Fahrenheit or higher than the melting point of lead. On the side turned away from the sun the temperature has not been measured but must be very low. The planet has certain dark permanent markings, and its surface is probably as rough as that of our moon. Our conception of the surface of Mercury must be that of a desert-like area, intensely hot on the illuminated side and extremely cold on the dark side, with no possibility of change in its features except through the slow processes of disintegration due to temperature.

Venus Has an Atmosphere

When we pass to Venus, the Hesperus of the Greeks, and the brightest of all the planets in the sky, we find quite different physical conditions. Its average distance from the sun is nearly three fourths that of the earth and its mass about four fifths as great. In many respects it is almost a twin to the earth, having nearly the same size and density and about nine tenths the surface gravity. An object weighing 100 pounds on the earth would weigh 85 pounds on Venus.

It has an extensive atmosphere, probably considerably less dense than that of the earth and is surrounded by what appears to be a perpetual layer of clouds. It is doubtful if we ever see the actual surface of Venus, the few vague markings which have been observed being quite possibly areas where the clouds have temporarily dissolved into a thick haze, much as fog dissolves over the earth. This cloud layer unfortunately prevents us from carrying our observations of temperature and atmospheric composition to the surface of the planet, and even the rotation period of the planet is very uncertain.

In the absence of permanent surface markings the only method of deriving the length of the day on Venus is from observations with the spectroscope. The rotation of the planet would cause one edge of the disk at the equator to approach us and the other to recede from us and thus should produce an inclina-

tion of the spectral lines. Several observers have made careful measures of the spectrum of Venus but have been unable to detect any appreciable inclination. This would indicate that the rotation period of Venus must be long, at least several days, although probably not so long as its period of revolution about the sun.

Quantities of Carbon Dioxide

Two interesting results have been found from spectroscopic studies of the light reflected from Venus. The first is the absence of any appreciable amount of oxygen and probably of water vapor above the cloud level from which the light is reflected; and the second is the presence of carbon dioxide gas in large quantities in this region of the atmosphere.

The intensity of the carbon dioxide bands is such as to correspond to a length of path of the order of half a mile through this gas at atmospheric pressure. It is, of course, quite possible that considerable amounts of oxygen and water vapor exist in the atmosphere of Venus below the cloud level which forms the limit of penetration of the spectroscope, although in the case of oxygen, at least, we should expect some spectroscopic evidence if conditions were at all analogous to those above high clouds in the atmosphere of the earth.

As all know, plant life consumes carbon dioxide and gives out free oxygen, and the suggestion has repeatedly been made that the free oxygen in the earth's atmosphere is wholly of vegetable origin. If, as Russell suggests, any original free oxygen in the atmosphere of Venus was exhausted in the oxidation of the rocks of the surface and plant life did not develop, we should find here an explanation of the existing spectroscopic evidence. Since we are ignorant of conditions below the cloud layer on Venus, such a hypothesis is necessarily speculative.

Nearly all astronomers agree, however, that on general considerations Venus should be better fitted than any other planet for the existence of such life as is known upon the earth.

Temperature of Venus

Measurements of the temperature of Venus, like the spectroscopic observations, are limited to the level in the atmosphere above the cloud layer and can not give us information regarding temperatures on the surface of the planet. There seems to be some evidence that in the atmosphere of Venus, as in that of the earth, an isothermal layer or stratosphere exists where the temperature is not far from uniform throughout a considerable depth.

This temperature in the case of Venus is about 25° below zero Fahrenheit, 40° warmer than that for the earth. The fact that temperatures of the same order are found for the illuminated and the dark sides of Venus is an argument against a very long period of rotation, at least one approaching the 225-day period of revolution about the sun. The temperature at the surface of Venus is doubtless much higher than that of the upper levels of its atmosphere and probably is also higher than that of the surface of the earth.

Conditions on the Moon

The next planet in order of distance from the sun is the earth with its attendant satellite, the moon. The temperature of the moon with no atmosphere to blanket and equalize the sun's radiation and with its long period of rotation is subject to enormous variations. The surface exposed directly to the sun's heat reaches a temperature close to that of boiling water, while that of the dark side is about 250° below zero Fahrenheit. The effect of the absence of an atmosphere and of the low heat conductivity of the materials of its surface is strikingly shown by temperature

measurements at the time of a lunar eclipse.

During the partial phase the temperature drops very rapidly, then slowly during totality, remains nearly stationary for a few minutes and then rises abruptly as the shadow passes away. The large differences of temperature between day and night so familiar to us on a desert on the earth are due mainly to the low humidity of the air, since the presence of water vapor serves to reduce the sun's heat during the day and to lessen the radiation from the earth during the night. On the moon where there is neither water vapor nor any other gas we find an extreme case of such conditions, the surface heating and cooling with extraordinary rapidity.

The Earth's Atmosphere

It is unnecessary to comment extensively upon the earth or its atmosphere. There are, however, one or two facts of interest which should be considered in relation to the planets in general.

The mean temperature of the whole earth is 57° Fahrenheit and of the tropical zones about 79°. The composition of dry air at the surface of the earth is about 78 per cent. nitrogen, 21 per cent. oxygen and 0.9 per cent. argon, with very small quantities of carbon dioxide, ammonium, hydrogen, helium and other gases. In moist air the amount of water vapor may exceed one per cent. As we go to higher levels in the atmosphere these percentages change very rapidly and above 50 miles the atmosphere theoretically should be composed almost wholly of hydrogen.

It is not known, however, whether any such amount of hydrogen actually exists nor can its presence be detected spectroscopically as in the case of oxygen, water vapor and carbon dioxide. The mass of the earth is sufficient to retain a hydrogen atmosphere almost indefinitely, but the question whether it is present or not must await methods of study of the upper atmosphere which we do not as yet possess.

The Earth as Seen from Planets

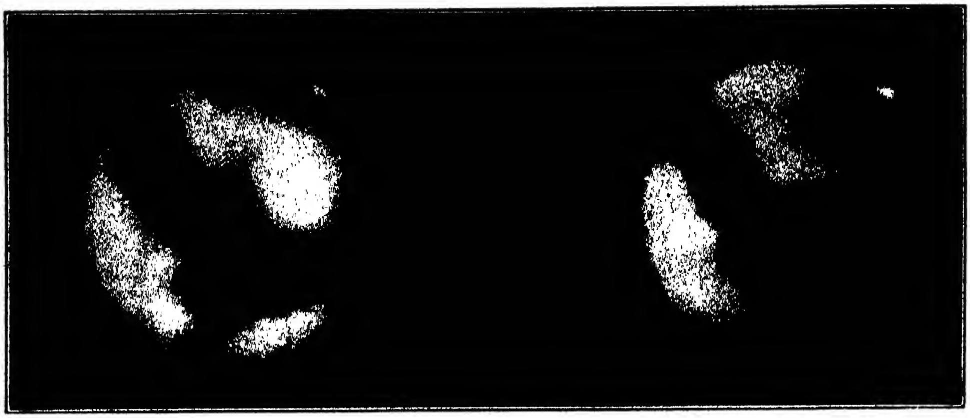
An interesting question regarding the earth is its telescopic appearance as seen from other planets. About half of the earth's surface, on the average, is covered with clouds and these would appear as conspicuous areas because of their high reflecting power. The seas and other large bodies of water would shine brilliantly when reflecting sunlight directly to the observer, but would be dark when seen at less favorable angles. Snow- and ice-covered areas, varying with the seasons, would be prominent, and large forested regions, deserts and grass land could probably be detected by their differing colors.

All the surface features, however, would have to be viewed through the depth of the earth's atmosphere with its dust and haze and all the effects of scattering and reflection of light which it produces. The result, as Russell states, would be that an observer on Venus could hardly see objects less than 50 miles in diameter and would have great difficulty in distinguishing permanent features because of varying clouds.

The Canals of Mars

The planet Mars has attracted more popular interest and has probably been observed more extensively than all the other planets combined. This is not surprising, for, although a small planet with one half the diameter and one tenth the mass of the earth, it comes nearer to the earth than any other large planet except Venus. It has an atmosphere, although not a dense one, and unlike Venus we can observe its surface directly and find there numerous conspicuous and in some respects unique markings.

The period of rotation, the Martian day, has been determined with great accuracy and is 24 hours and 37 minutes, so nearly like our own that features on



TWO VIEWS OF MARS

TAKEN ABOUT A MONTH APART AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY WITH THE 60-INCH TELESCOPE. THE DIAMETER OF MARS IS ABOUT ONE HALF THAT OF THE EARTH AND ITS MASS ABOUT ONE TENTH. IT HAS AN ATMOSPHERE, THOUGH NOT A DENSE ONE. ITS GENERAL SURFACE IS REDDISH WITH SHARPLY BOUNDED AREAS OF GRAY OR DULL GREEN. THE POLAR CAPS CHANGE CONSPICUOUSLY, BEING LARGEST IN THE MARTIAN WINTER AND SMALLEST IN SUMMER. SOME ASTRONOMERS THINK THAT A CERTAIN NETWORK OF FINE MARKINGS ON THE SURFACE OF MARS IS OF ARTIFICIAL ORIGIN, BUT THIS EXPLANATION IS NOT GENERALLY ACCEPTED.

the surface of the planet are seen in closely the same position by an observer on successive nights.

The color of the general surface of Mars is reddish, from which comes the name the ruddy planet, but nearly one half its surface is covered by darker areas of a gray or dull green color sharply bounded in many cases. At the poles of the planet are two brilliant white areas, the polar caps, which show conspicuous changes with the Martian seasons, being largest in winter and smallest in summer. The southern polar cap has been known to disappear completely toward the end of the summer season, but the northern always remains visible, although greatly diminished in size. It is difficult to conclude that these areas are not actually covered with snow or ice, although the rate of melting indicates that the deposit must be relatively thin.

Accompanying the melting of the polar caps are certain changes, which appear to be well established, in the color of the large dark areas toward the equator of the planet. The general tendency is for these areas to become darker and more prominent in the spring season for each hemisphere and to fade and become more yellow in the autumn of the year. Lowell and others have ascribed these changes to the presence of vegetation.

Associated with this effect is the vexed question of the canals on Mars, observed by Lowell as fine narrow straight markings making a network covering much of both the dark and the reddish areas of the planet. That fine details are present on the surface of Mars which could form a basis for Lowell's observations is beyond question, but the existence of markings which can hardly be interpreted as of other than artificial origin is subject to serious doubt in view of the results of other experienced observers.

PROOF OF ATMOSPHERE

The presence of an atmosphere around Mars has been proved in a variety of different ways. One of the most interesting of these is through such a

series of photographs in light of different colors as was first made by Dr. Wright of the Lick Observatory. The photograph in red light shows a great quantity of detail on the surface of the planet, while that in violet light shows almost none.

The red light can pierce through the haze of the planet's atmosphere, while the violet light has little penetrating power. Moreover, the size of the image in violet light is greater than that in red light, thus indicating that the atmosphere stops the violet light above the level of the surface and gives the appearance of a larger disk. Clouds have occasionally been observed in the atmosphere of Mars but are comparatively infrequent.

Spectroscopic investigations of the atmosphere have been made by many observers, notably at the Lick, Lowell and Mount Wilson observatories, mainly with a view to determining the amount of oxygen and water vapor.

Dr. Campbell's observations, made by him when at the Lick Observatory, proved definitely that the quantity of these gases in the atmosphere of Mars must be small, and later observations have abundantly confirmed his results. The most recent investigation undertaken with the powerful equipment at Mount Wilson indicates that the amount of free oxygen above a given area of the surface of Mars can not exceed one tenth of one per cent. of that above an equal area of the earth's surface at sea level.

While the presence of water vapor seems to be well established by the existence of the polar caps, the total amount of water contained in them need not exceed that in a large lake and could hardly be detected in the form of water vapor distributed throughout the planet's atmosphere.

Temperatures on Mars

Measurements of the temperatures of Mars have led to most interesting results. When Mars is nearest the sun the temperature of the surface exposed to the strongest solar radiation reaches about 60° Fahrenheit. When Mars is farthest from the sun this drops to about the freezing temperature. The polar caps may become extremely cold, more than 100° below zero Fahrenheit.

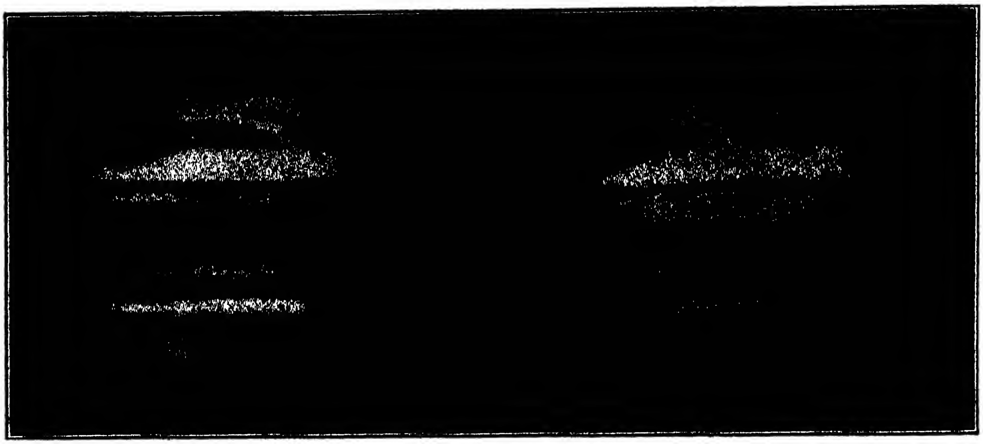
The important question of the temperature of the dark side of Mars is a very difficult one to answer because of the very small area which can be observed, even at the most favorable phase. The observations indicate that the temperature must be at least 40° below zero and perhaps considerably lower.

If we sum up conditions on Mars we find a small planet with little water vapor and very little oxygen whose sunlit surface in the tropics only at the most favorable times reaches temperate conditions and during much of the time is at a freezing temperature. Every 24 hours, as the planet rotates, the surface reaches a temperature of at least 40° below zero. It is clear from the observations that the atmosphere of Mars is of such low density that its shielding effect is small, and that the surface warms and cools with a rapidity far greater than that of any desert on the earth and only less than that of the moon itself.

Under such conditions if we can conceive of any vegetation on Mars it would seem that it must be of a rudimentary type which requires little nourishment from the atmosphere and gives out correspondingly little oxygen. The suggestion has been made that the free oxygen which may in past ages have formed a part of the atmosphere of the planet has been exhausted in the oxidation of the surface, and the general color of the surface is quite in keeping with this possibility.

The Asteroids

As we pass outward in the solar system beyond Mars we come to the zone of the asteroids, of which some 1,500 are known and many thousands doubtless



TWO VIEWS OF JUPITER

TAKEN AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY, THE ONE IN ULTRA-VIOLET LIGHT, THE OTHER IN BLUE-VIOLET LIGHT. JUPITER, ONE OF THE BRIGHTEST OBJECTS IN THE SKY, IS THE LARGEST PLANET, HAVING A DIAMETER ELEVEN TIMES THAT OF THE EARTH. THE MOST CONSPICUOUS FEATURES ARE THE BELTS WHICH EXHIBIT A GREAT VARIETY OF DETAIL AND COLOR AND WHICH OFTEN CHANGE RAPIDLY IN FORM. IT IS ALMOST CERTAIN THAT THESE ARE CLOUDS, PROBABLY NOT OF WATER BUT OF SOME SUBSTANCE THAT VAPORIZES AT A LOWER TEMPERATURE. JUPITER HAS NINE SATELLITES. FOUR OF THEM WERE DISCOVERED BY GALILEO IN 1610.

exist. They are small bodies, the largest less than 500 miles in diameter, moving in independent orbits around the sun and far too small to retain an atmosphere. Like the moon they must heat quickly on the side toward the sun and cool quickly as the sun's heat leaves their surface. The force of gravity is so low on the smallest of these asteroids that a hypothetical man could readily throw a stone from the surface into space and thus create an independent planet.

The Major Planets

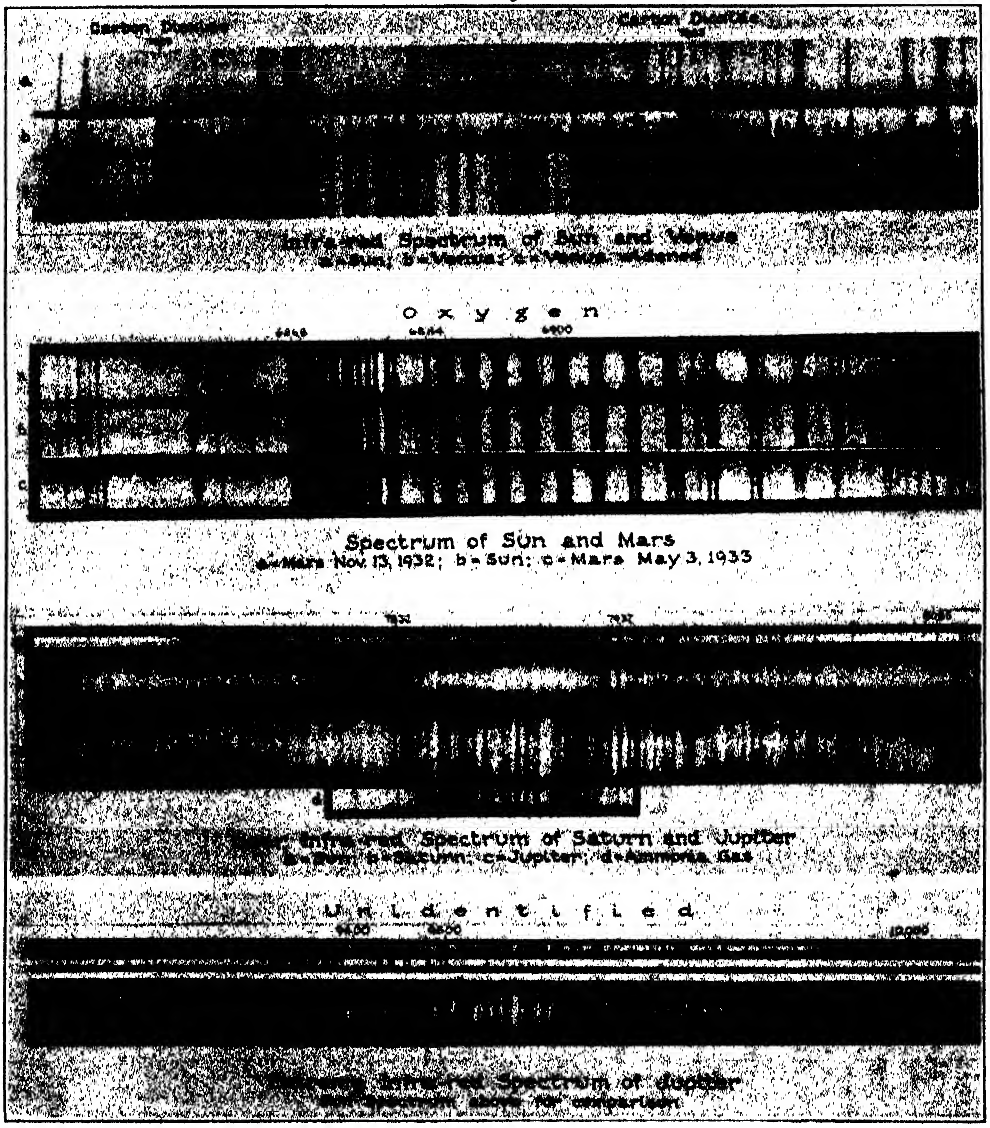
With the major planets Jupiter, Saturn, Uranus and Neptune we pass to an entirely different class of physical objects. They have large masses, rotate rapidly and are at such great distances from the sun that they receive very little heat.

Jupiter and Saturn have extensive systems of satellites, miniature solar systems in themselves. They have dense atmospheres of great depth which prevent us from seeing down to the surfaces of the planets, if such surfaces exist, and all their markings are subject to change, although in some cases they persist for long periods. Clearly they are atmospheric phenomena and may take place on an enormous scale. The great red spot on Jupiter, for example, was 30,000 miles long and 7,000 miles wide and lasted for many years, gradually becoming rounder and smaller until it has now almost disappeared. The white spot on Saturn discovered this year at the Naval Observatory was also very large and changed its form with great rapidity.

A remarkable fact about Jupiter and Saturn, and perhaps about Uranus and Neptune, as well, is that they do not rotate as solid bodies but more rapidly near the equator than in higher latitudes. The belted appearance of the planets, so striking in the case of Jupiter and Saturn, is probably associated with the character of their rotation.

Unknown Bands

The analysis of the light reaching us from these planets shows the presence of



SHOWING SPECTRA OF THE SUN AND PLANETS

TAKEN AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY. A GLOWING GAS OR VAPOR EMITS WAVES OF RADIATION, EACH HAVING A CHARACTERISTIC LENGTH. WHEN THESE ARE SORTED OUT BY THE SPECTROSCOPE AND THE SPECTRUM PHOTOGRAPHED, THE PRINT SHOWS A NUMBER OF LINES ON A CONTRASTING BACKGROUND. THE POSITION OF EACH LINE IN RELATION TO THE OTHER LINES IN THE SPECTRUM TELLS WHAT WAVE-LENGTHS PRODUCED IT. THE SPECTRA OF ELEMENTS DIFFER GREATLY; SOME CONTAIN BUT FEW LINES, OTHERS, THOUSANDS; BUT FROM WHATEVER SOURCE THE RADIATION IS DERIVED THE SPECTRUM OF A GIVEN ELEMENT IS ALWAYS THE SAME. IN THE SPECTROSCOPE, THEREFORE, THE ASTRONOMER HAS DEVELOPED A NEW TOOL AFFORDING ALMOST LIMITLESS POSSIBILITIES IN HIS STUDY OF THE NATURE OF THE PHYSICAL UNIVERSE.

numerous bands in the red and infra-red portions of the spectrum, some of which are very prominent, especially in the atmospheres of Uranus and Neptune.

The origin of most of these bands is still unknown, but recently Wildt and Dunham have identified several with bands produced by ammonia gas and methane. The bands due to ammonia are more prominent in the spectrum of Jupiter and those of methane in that of Saturn. Comparisons with laboratory results indicate that the ammonia present in the atmosphere of Jupiter is equivalent to a layer of gas 30 feet thick at atmospheric pressure. A minimum temperature of about 180° Fahrenheit below zero may be inferred from the observations.

It seems highly probable that the unknown bands in the spectra of the outer planets are also due to gases compounded of hydrogen and carbon, since hydrogen must be very abundant in their atmospheres.

The Rings of Saturn

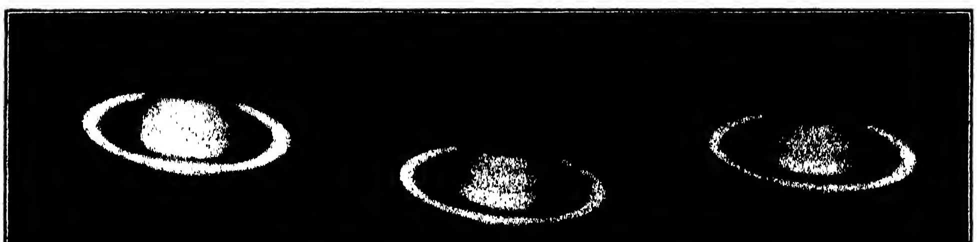
No description of the major planets is adequate without some reference to that unique feature of the solar system, the rings of Saturn. Although of extraordinary beauty and great mathematical interest, physically they are of less importance, since they possess no atmosphere.

It has been shown both by measurements of the reflected light and observations of the motions of different portions of the rings that they consist of a swarm of little satellites, each of which follows its own orbit about the planet. The thickness of the ring is extremely small, not more than 10 miles at most, and when its plane is turned toward the earth it is lost to sight for a few days, even in the most powerful telescopes.

Pluto, the Most Distant

The latest and most distant addition to the number of known planets is Pluto. Its mean distance from the sun is about 40 times that of the earth and its mass, the determination of which is subject to great uncertainty, is about one tenth that of the earth. Receiving but very little heat from the sun and plunged in the cold of space, this unexpected dwarf of the solar system is distinctly an object for sympathy.

Unlike the giant planets which are its nearest neighbors, Pluto is too small to have reserves in its own mass upon which to rely, and it has probably lost any atmosphere it may once have had, although some remnants of nearly inert gas may



THREE VIEWS OF SATURN

Taken at the Carnegie Institution's Mount Wilson Observatory with the 60-inch telescope. Saturn is unique in being encircled by three concentric rings which are composed of a swarm of little satellites, each of which pursues its own independent circular orbit around the planet, while moving in almost exactly the same plane. These rings, the outermost having a diameter of 171,000 miles, are extremely thin, probably not exceeding ten miles. Both Jupiter and Saturn have dense atmospheres which hide their surfaces, if surfaces actually exist.

still cling about it. Seen in the largest telescopes as merely a faint star it is probable that we shall never gain any considerable knowledge of its physical constitution.

Doubtful if Life Exists

It is clear from this outline of some of the conclusions regarding physical conditions upon the planets that only two of them, Venus and Mars, can by any stretch of the imagination be regarded as possible abodes of life. Of these Venus must, so far as we can judge, remain largely a subject for speculation.

We can not see its surface or analyze its lower atmosphere, and although the absence of oxygen in its upper atmosphere and the apparently long period of rotation are unfavorable factors, it is quite impossible to state definitely that life may not have developed upon its surface.

With Mars the case against the existence of life appears much stronger. The surface of the planet can be studied directly and the atmosphere examined throughout its entire depth. It appears like a dying world with little or no oxygen and little water, subjected daily to great extremes of temperature as the sun rises and sets upon its surface.

Modern theories of the origin of the system of the planets indicate that the probability of the development of such systems among the myriads of stars is very much lower than we used to believe, and that they may be relatively few in number. Similarly, as our knowledge of the planets increases, we may be led to the conclusion that quite possibly the earth is the only planet which can at the present time support life, and so that in the universe as a whole life is a much rarer and more precious thing than we once realized.

A ZOOLOGIST IN THE PANTANAL OF THE UPPER PARAGUAY

By JAMES A. G. REHN

SECRETARY, ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

EVERY zoologist, and probably every botanist, critically studying any part of the Neotropical biota is confronted with numerous historic species described from "Brazil," without further exact locality. Probably no single large area of the world, except the classic "Indes orientales" of the older French workers, has been so frequently and indefinitely given as the habitat of this or that new discovery. The particularly exasperating angle of this indefiniteness is that in but a small percentage of cases can a modern student determine who originally secured the material, or even approximately where. Very frequently the type material has long since disappeared from collections. The many problems raised by modern intensive work can usually be solved in such cases by topotypic specimens, or individuals taken subsequently at the original locality, but this involves definite knowledge of the latter.

The vast extent of Brazil, reaching from 5° N to as far as 33° S, and with an area slightly larger than the United States, exclusive of Alaska or all Europe, as well as a diversity of surface conditions equaled by few other countries, is often unrealized even by otherwise well-informed people.

Virtually every student of the Neotropical biota is involved in the tantalizing indefiniteness of the early literature, as a true knowledge of the character and relationships of the life of southeastern Colombia, eastern Ecuador and Peru and northeastern Bolivia can not be secured without broad consideration of that of Amazonian Brazil, constituting as these areas do but parts of a single great cohesive biotic province, probably the richest in the world in the diversity of its life. The frequent use of "Brazil" as an original locality may thus constitute a taxonomically disconcerting factor when studying the life of any Amazonian area, even outside of the political boundaries of Brazil.

Roughly, the more outstanding biotic areas of Brazil are: (a) the relatively old mountain area to the north, separating that country from Venezuela and the Guianas; (b) humid, usually forested, Amazonia; (c) the ancient eastern and central plateaus and mountain groups which are often in large part semi-arid, as well as treeless "chapadão" over much of the western prolongation of this area in the Amazon-Paraguay divide; (d) the heavily forested belt of the coastal mountains of southeastern Brazil; (e) the relatively high and cool Paraná pine (*Araucaria*) district, in the same general region, and (f) the Paraguay River drainage of Matto Grosso, most of São Paulo and the western part of the other more southern states, which in the immediate vicinity of the Paraguay becomes a "pantanal" or seasonally flooded river plain of broad expanse. Many further subdivisions can be suggested by the student of Brazilian faunistics, but the major ones given will illustrate the fundamental diversity of the basic factors affecting animal and plant life in Brazil.

The Brazilian state of Matto Grosso lies in the south-central part of the country, in contact with Bolivia and Paraguay along its entire western boundary, and embraces within its limits a large

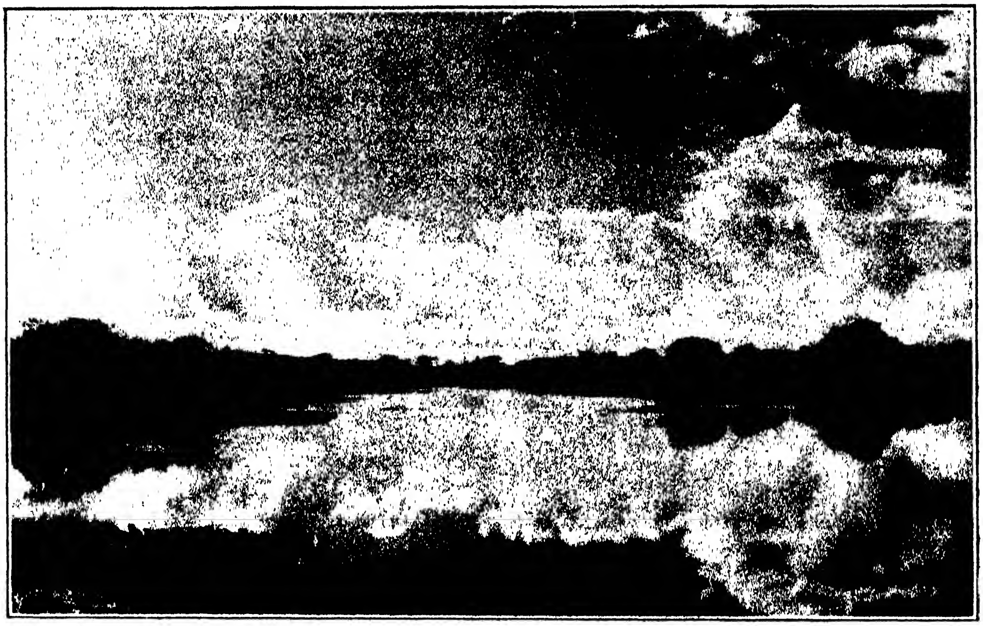


FIG. 1. OX-BOW CUT-OFF OF RIO PARAGUAY AT DESCALVADOS SHOWING FLOATING MATS OF "CAMALOTES," A RELATIVE OF OUR WATER-HYACINTH, AND THE TANGLED, JUNGLY CHARACTER OF RIVERINE SCREEN FOREST. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

part of the Brazilian section of the Paraguay River drainage. The head streams of a number of the chief southern tributaries of the Amazon are similarly included. The plateau which forms so much of the Amazon-Paraguay divide, with its "chapadão," is also largely in Matto Grosso. The state has an area about twice that of Texas, or to be exact 532,683 square miles. Few elevations within its borders reach as much as 3,000 feet above the sea, but what is lacking in contour diversity is made up in other physiographic contrasts. To the northward we have Amazonian forests, particularly along the stream courses, passing into the "chapadão" and open forest country of the plateau divide, succeeded southward by the vast, nearly level, low river plain, elevated but slightly above the river, and during the rainy season, which extends from October to April, and for several months thereafter, is almost entirely flooded to a depth of from a few inches to as much as six feet. This country is the "pantanal" of the Brazilian, in general consisting when dry of open grassy campo-like plains dotted with usually circular islands of tangled forest, known as caapões (pronounced capõns), and with riverine screens of similar jungle forest. Many shallow channels, called "corixos" (corichos), filled with tall sedge and papyrus, wind through the pantanal or spread out in broad sloughs. During the dry season rain may not fall for as much as three and a half months, the campo grass-land bakes dry, the grass sun-cures, the corixos largely dry up, being merely water pockets and not flowing stream courses, and many of the caapões trees become leafless. The native Borero Indian cattlemen then burn off the dry grass, and the smoke of grass fires is much in evidence. While the

temperature may at times be high, the dry season is "winter" in the pantanal, and cold south winds, the backwash of Argentine "pamperos," blow for days at a stretch; the writer has seen the temperature drop from 97° to 40° F. in ten hours.

To the systematist who has worked on the fauna of Matto Grosso the name of one field collector of the past is particularly familiar. Probably his labors placed in the hands of students as great a variety of material from several localities in South America as any one of this group of scientific pioneers. It is pleasing to know that Herbert H. Smith was an American, and that virtually all his vast Brazilian collections are housed in American institutions. In the breadth of his work and its scientific results, his Brazilian efforts place his name in that coterie of zoological trail-breakers in Brazil which includes Spix, Natterer, Bates and Wallace. Of these Natterer was the only other one who touched the state of Matto Grosso, the northern portion of which he crossed on his way to the Rio Madeira, a trail of many perils then and hardly a pleasure stroll to-day.

Smith's work in Matto Grosso was done at two localities: first, the vicinity of the old city of Corumbá on the Rio Paraguay, bordered on the north and east by low pantanal, with the elevated square-cut massif of Urucúm on the south; and second, the town of Santa Anna de Chapada, twenty or more miles northeast of Cuyabá, capital of the state, situated on the Paraguay-Amazon divide and near the characteristic "chapadão" of that area. At these two localities, but especially at Chapada, Smith and the other members of his party collected intensively for several years, and amassed really amazing collections of mammals, birds, reptiles, fishes, insects and other animals, which served as the base for classic studies by Cope, J. A. Allen, Cal-

FIG. 2. DESCALVADOS FROM THE AIR

SHOWING THE SINUOUS COURSE OF THE RIO PARAGUAY, AND THE DIVERSIFIED COVER CONDITIONS OF THE PANTANAL. DESCALVADOS IS THE LARGEST SETTLEMENT ALONG SOME THREE HUNDRED MILES OF THE PARAGUAY BETWEEN CORUMBÁ AND SÃO LUIZ DE CAÇERES. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

FIG. 3. PANTANAL CONDITIONS IN APRIL AND MAY

THE LATTER PART OF THE WET SEASON. THE TERMITES' NESTS ARE SOMETIMES UNDERCUT BY THE WATER AND TOPPLE OVER. THE WHITE BIRDS IN THE DISTANT SLOUGH ARE LARGELY WOOD IBIS, WHICH FIND THESE AREAS PRODUCTIVE FEEDING GROUNDS. WHEN THE SAME COUNTRY WAS LARGELY DRY, WATER BIRDS WERE MUCH LESS IN EVIDENCE. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

vert and many others. Considerable portions of these vast collections are yet unreported, while studies on other sections are being made by a number of specialists. My personal interest in Matto Grosso zoology came through work years ago on a portion of Smith's series of Orthoptera.

In 1930 an expedition was organized in the United States, having as two of its objects the securing of motion pictures of the wild life, human and animal, of parts of Matto Grosso, and the examination of little-known country on the upper Rio Xingú, one of the main southern tributaries of the Amazon. It was known as the Matto Grosso Expedition, and had attached to it as anthropologist and archeologist Mr. Vincent M. Petrullo, of the University Museum of Philadelphia, and subsequently the writer was added to the expedition as zoologist, representing the Academy of Natural Sciences of Philadelphia.

Mr. Petrullo's splendid work among the little known peoples of the upper Rio Xingú (pronounced Shin-gú) has been ably described by him in the publications of the University Museum.[1]

The personnel of the Matto Grosso Expedition other than native help comprised eighteen persons, all but four of whom were American. The main party left New York in December, 1930, and

[1] *Museum Journal*, xxiii: No. 2, 91–173, pls. xix–xxiv, map, 1932.

the last members of the expedition returned to the United States about a year later. In order to insure the best possible success in jaguar hunting, a number of hounds trained on puma in the United States were taken. The value of these dogs over the average native one for trailing was beyond question, in spite of declarations by some that imported hounds would not be as useful as native dogs. The expedition was the fortunate possessor of its own short-wave radio equipment and for about five months had the use of an amphibian plane and crew of three. This was of exceptional value in connection with the anthropological reconnaissance of the upper Rio Xingú.

In order to permit the best hunting, the stay of the expedition was planned to cover the entire dry season, when the pantanal country, where the largest type of jaguar known occurs, is driest and trailing has the best chance of success. For other groups of animals than mammals, however, with the possible exception of birds, the dry or winter season, with its very cool spells and its lack of rain was, as in the American tropics as a whole, distinctly less productive than the wet season. While the latter season is the one more trying to the field worker, it is in many ways more productive in results. For anthropological work, with its relative ease of land travel, and for aerial reconnaissance, the dry season is distinctly the better.

FIG. 4. JAGUAR AND PUMA FROM THE PANTANAL

THE LARGE MALE JAGUAR IN THE CENTER WEIGHED 290 POUNDS SOME HOURS AFTER DEATH. THE HEAVY BUILD AND POWERFUL FORELIMBS OF THE JAGUAR ARE HERE WELL CONTRASTED WITH THOSE OF THE MORE SLENDER PUMA. THE KILLING POWER OF THESE MAKES THE JAGUAR A FAR MORE SERIOUS PROBLEM TO THE CATTLEMAN. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

The base of the Matto Grosso Expedition was established at Descalvados, on the upper Rio Paraguay, the station of the Brazil Land and Cattle Company, well over two hundred and fifty miles by stream and about one hundred and seventy-five in an air-line due north of Corumbá. Descalvados is a "xarqui" (pronounced char-kee), or jerked beef, slaughtering and drying plant, and under its now deceased manager, John Gordon Ramsey, it has served in the past two decades as a base for several zoological expeditions, while the Roosevelt-Rondon Expedition visited it on the way to Tapiropoan and on over the chapadão to the descent of the Rio Roosevelt. Ramsey, a former Texas sheriff and cattleman, will always remain an unforgettable figure in the memory of those fortunate enough to have had the friendship of this courageous and generous exemplar of the best in our pioneer days. At Descalvados, under conditions entirely different from those of our West, he had developed in the Borero Indian cattlemen an unusual loyalty on account of his fairness, coupled with the application to the guilty of the justice of our old frontier. In a land where life is still held lightly, he was to the evil-doer a living personification of the maxim that the way of the transgressor is hard.

The Boreros of Descalvados represent a sadly decultured branch of that distinctive people, and have been in contact with white men for many decades, as the upper Paraguay served as part of the route of the Spanish conquistadores on the long trail from Asuncion to Lima, a hard journey to-day and an almost unbelievably arduous one in the sixteenth and seventeenth centuries. The Descalvados Boreros in the past decades have acquired a pronounced Negro admixture, adopted the white man's clothes and largely speak Portuguese, as well as their own tongue. On the Rio São Lourenco, an important eastern tributary of the upper Rio Paraguay, about two hundred miles southeast from Descalvados, one of the branches of the Borero people lives in essentially their primitive condition, having been hostile to whites until a few decades past. Through the cooperation of General Candido Mariano da Silva Rondon, the distinguished Brazilian administrator and explorer, whose interest in the welfare of the aborigines of his country is sincere and understanding, members of our expedition were permitted to visit these interesting people and secure motion pictures and sound records of their dances, songs and mode of life. Brazil, it is pleasing to know, has adopted a policy of protecting its still considerable Indian population from exploitation and pseudo-scientific "racketeering," yet providing for genuine scientific recording and preservation of anthropological and ethnological information before inevitable changing conditions make this impossible.

The scientific members of the Matto Grosso Expedition look back with pleasure on the uniformly cordial cooperation and invaluable assistance received from the Brazilian Government and all its officials with whom they came in contact. No more generous consideration has been extended to the writer in field work involving seven different Latin-American countries. The cooperation of Brazilian scientists was equally generous and helpful, fully in keeping with the extreme cordiality which has marked Brazilian-American relations of all character.

FIG. 5. RED OR MANED WOLF (*CHRYSOCYON BRACHYURUS*)
ONE OF THE MOST STRIKING AND DISTINCTIVE ANIMALS OF THE RIO PARAGUAY BASIN.

The Rio Paraguay at Descalvados, where the writer spent the four months between May and October, occupied with hunting and zoological collecting, is a stream about two to three hundred yards wide, swift and powerful in spite of its low elevation (approximately six hundred feet) there, about two thousand miles from the sea. The river has many holes, some being over forty feet deep at low stages of the water, although toward the end of the dry season shoals often give trouble to the shallow draught river steamer, which operates between Corumbá and the town of São Luiz de Caçeres, some seventy miles upstream from Descalvados. Caçeres is an old settlement and has figured conspicuously in the past history, and the natural history, of Matto Grosso. In the past it was also called Villa Maria, and is so quoted in some of the older scientific literature.

Some fifty miles or so down stream from Descalvados the Paraguay breaks up into several channels which squirm and twist through forest-bordered pan-

tanal. The navigation of these tortuous waterways requires skill and experience at the helm of the steamer, particularly with freight barges lashed on the sides, as is the usual custom.

A hundred or more miles above Corumbá the various channels merge into a deep powerful stream, which flows among the eastern ridges of a rugged mountainous area. This uplift, rising out of the pantanal and the ghostly lakes of Uberaba, Guiba and Mandioré, stretches far off westward into Bolivia. The July airplane panorama of these apparently ancient mountains, rising from the flooded pantanal and reaching off toward the setting sun, range beyond range, deep into Bolivia, is something not readily forgotten. Their dry slopes show many candelabra cacti (*Cereus peruvianus*), which are locally called urumbéva in Brazil, and are sometimes as tall as forty-five feet, while the hill slopes are also dotted with the pink and yellow flowers of the peúvas. We know little of these mountains or their animal life. They have never been accurately surveyed and are charted on the best Brazilian maps as just surpassing three hundred meters in elevation. With our plane we cleared the summit of one of the higher peaks by about two hundred feet and found its height was approximately four thousand feet above the level of the Rio Paraguay.

FIG. 7. TREE PORCUPINE (*COENDU*)
(PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

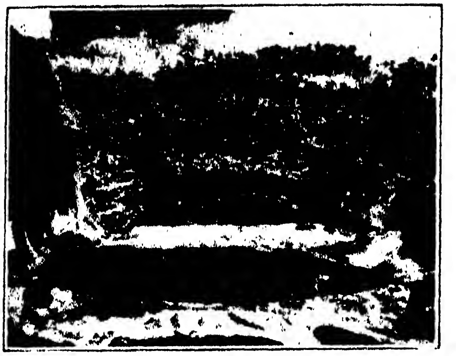


FIG. 6. THE LARGE OTTER OR "ARE-INHA" (*LUTRA BRASILIENSIS*)
THE FLATTENED TAIL IS EVIDENT IN THE PHOTOGRAPH. THE FRINGED LEATHER APRON OF THE BORERÓ CATTLEMAN IS SEEN ON THE FIGURE TO THE LEFT.

To return to the Paraguay at Descalvados, the surface of the river generally bears floating islands or marginal fringes of "camalotes" (*Eichhornia* and *Pontederia*), larger cousins of the water-hyacinth of our southern states. These mats of vegetation often solidly choke the channels of ox-bow cut-offs which lead back from the main stream. Quiet shallow pools or small lagoons with little or no current will shelter the glorious "rainha dos lagos" or queen of the lakes, a species closely related to the *Victoria regia* of more northern South America.

The dense fringe of jungly forest which borders the river, and for long distances forms a screen cutting off the hinterland, is made up of a large number of species of trees. This forest, being more generally inundated during high water than the drier caapões, has a different fascies. It is what might be called more truly tropical in the more frequent palms, of which the carandá palm (*Copernicia cerifera*) is the most abundant, while others are the "auassú" (*Orbignia speciosa*), the burity palm (*Mauritia*) and the great-leaved "acury" (*Attalea*), a near relative of the Central American corozo or manaca palm. Among the many other riverine forest

components may be mentioned great wild figs or "figueiras" (*Ficus*), species of *Cercopia*, locally called "umbaubeira," which is the "guarumo" or trumpet tree of much of Spanish America, the false dragon's blood (*Heliocarpus americanus*) and the "pão santo" (*Bulnesia sarmienti*). The fringe forest is often almost solidly mantled with a blanket of vines, tying all into mounds or domes of green, as seen from the stream. When the water is high all the land bearing the riverine forest is inundated or at least but a few inches above the flood.

The open pantanal of campo character is generally treeless, short-grassed, level, sometimes with an open grove-like tree cover of species of relatively low stature, most of which become completely leafless by the end of the dry season. The dense caapões are scattered like islands over the campo and wetter pantanal, usually elevated a few feet above the general level and thus generally dry most of the year, serving as refuges for many mammals during the flood time. They are generally circular in outline, which is particularly pronounced when the pan-

FIG. 9. GIANT ARMADILLO (*PRIODONTES GIGANTEUS*)

THIS SPECIMEN, THE FIRST OF THREE CAPTURED ALIVE, DIED IN TRANSIT THE NIGHT BEFORE REACHING OUR HEADQUARTERS. THE GREAT DIGGING CLAWS ARE USED BY THE PRIMITIVE BORERÓS IN ONE OF THEIR DISTINCTIVE NECK PENDANTS. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

FIG. 8. FALSE VAMPIRE BAT (*VAMPYRUM SPECTRUM*)

THIS SPECIMEN MEASURED THIRTY INCHES ACROSS THE FULLY EXTENDED WINGS. IT KILLED AND DEVOURED A SMALLER BAT WHICH WAS PLACED IN A CAGE WITH IT. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

tanal is seen from a plane, and rise quite sharply from the campo, with no definite transition area. The densely matted tree growth is made up of many kinds, most conspicuous of which are the great-leaved "lixeira" (*Curatella americana*), species of wild fig (*Ficus*), several palms, the giant jatobá (*Hymenaea*), species of *Inga*, called "ingasinho," and lianes of varied and strange type, of which the "cipó de escada" (probably a *Bauhinia*), with its ladder-like convolutions, draws prompt attention. On the few low, rocky hills near Descalvados—apparently isolated remnants of the mountains to the south already mentioned—one finds a more xerophytic vegetation, with candelabra cactus, low spiny agave-like types and the yellow and red flowered peúva trees, locally "peúva amarella" (*Tecoma ochracea*) and "peúva roxa" (*T. ipe*). These beautiful trees in the dry season are mantled with great clusters of golden yellow and purplish pink trumpet-like blooms, although then quite leafless. The wet swales of the pantanal, with their standing water, are densely grown

FIG. 10. WATER BIRD LIFE ON THE PANTANAL AT THE END OF THE WET SEASON

THESE ARE MAINLY EGRETS AND WOOD IBIS. THE STANDING LARGE BIRDS WITH BLACK NECKS ARE JABIRÚS. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

up in a tall coarse sedge, which has much the same cutting propensities as Florida saw-grass. Often these areas occupy many acres, filling every slight depression in the land. In the deepest wet spots are dense eight-foot stands of papyrus. Many shallow lagoons are scattered over the pantanal, bearing great mats of "camalotes" and the "rainha dos lagos" much as embayments of the more truly riverine sections. Until the middle of the dry season the recurrent splashing of water, when crossing the corixos or shallow pools, is the regular accompaniment of pantanal travel in the saddle. This brief picture of the major features of pantanal landscape will give a background for comments on its more evident animal life.

Any mention of the great cats at once brings forward the African lion as the standard of comparison. In reality he is unique among the larger cats in a number of respects and correspondingly non-representative. None of the other large felids are as gregarious as the lion is often found to be, and they are as a whole more forest-loving. One will not find the various forms of jaguars or pumas congregating in fair-sized groups, and their siestas are by preference taken in heavy cover. Consequently, they are far less evident features of the landscape than lions are in Africa. The species or subspecies of the jaguar of the pantanal region (*Felis onca milleri*) is the largest form of this greatest of New World cats. The relationships of the various forms of jaguars have been the subject of recent investigation by Messrs. Nelson and Goldman, and the technical name here used was recently proposed by them for the pantanal subspecies.

It is a common thing, even among otherwise well-informed people, to look upon the jaguar as merely an American counterpart of the leopard. In reality they have no resemblance in habits, much less in size and build. The jaguar is a far heavier animal, with more robust limbs, lower set and thicker body, shorter, heavier tail and more powerful head and neck. No Old World cat has proportionately as heavy fore limbs as the jaguar. The Matto Grosso Expedition secured fifteen jaguars, of which the largest weighed 290 pounds, a number of hours after death. This cat in life undoubtedly would have scaled 300 pounds, or equal in weight to a small African lion. The relative size of this huge male, as compared with a fair-sized female jaguar and an average puma, is shown in Fig. 4.

When cattle are not available or not particularly sought, the pantanal jaguar preys upon tapir, deer, capybara, rheas and even the alligator-like jacarés or caimans. It has even been known to

attack the great ant-eater, with fatal results to both, and doubtless will eat armadillos and various of the larger birds. Although he is an almost omnivorous feeder, tapir and capybara seem to be particularly liked. The hides of tapir often show deep claw marks where jaguars have attacked and been swept off by the tapir's headlong rush through dense brush, usually for the relative security of deep water. Nevertheless, the jaguar swims well and crosses large or swift bodies of water without difficulty. During the inundation of the wet season jacarés become more widely spread over the vast extent of the pantanal. As the flood sheet recedes these unprepossessing saurians are encountered wandering over dry land considerable distances from any water. In hunting one often finds the mummified remains of jacarés, always on their backs with the lower surface torn away, showing where some hungry jaguar stalked and slew.

The jaguar's hunting is generally done at night, while the day is usually spent in the depth of some dense caapõe. To these places the cats generally retire in the early morning, often taking a preliminary roll in a bed of grass or sedge. These beds are easily recognized. The sleeping place may at times be some distance from the "kill," if one has been made, or the cat will sleep near the kill, feeding again later. The position of the kill is generally evident from the attendant group of black vultures or "urubús." Apparently long distances are covered by jaguars in search of food, and in hunting them with hounds cold trails are sometimes followed for many miles before the spoor becomes fresh enough for the younger, "hot-trail" dogs. In one case we followed a trail for twelve miles before the cat came to bay.

Naturally cattlemen are deeply interested in the spotted killer, which takes a considerable toll of calves, cows and

FIG. 11. WOOD IBIS FLYING OVER FLOODED PANTANAL

THE SHRUB IN THE FOREGROUND IS KNOWN LOCALLY AS "CANUDO" OR "ALGODÃO DO PANTANAL" (WILD COTTON) (*Ipomoea fistulosa*) AND OCCUPIES A DEFINITE BELT IN THE DESCALVADOS PANTANAL. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

FIG. 12. JAWS OF THE WOLF FISH (*RHAMPHIODON*)
ONE OF THE HIGHLY SPECIALIZED MEMBERS OF THE GREAT FAMILY CHARACINIDAE. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

steers, while much more rarely a bull, taken off guard, may be attacked. Native hunters kill a considerable number for their hides, the ranchers sometimes systematically endeavor to wipe out a particularly persistent cattle killer, yet jaguars remain in considerable numbers, unseen and usually unheard.

Pumas (*Felis concolor osgoodi*) are probably less numerous than jaguars in the pantanal, seem more partial to the drier areas and, being smaller, play a less important part. Occasionally a family group of as many as three will be encountered. Such a trio one day furnished us with two study specimens and a live individual. When closely pressed by hounds, they invariably tree, while jaguars may elect to bay on the ground, as I saw them do on two occasions. In dense growth a large jaguar at bay on the ground is a serious opponent for man or dog, as visibility may extend but a few yards, and a charging jaguar has speed all out of proportion to his build. The wise dog gives plenty of room, the careful hunter takes no chance of merely wounding the jaguar by a hasty shot. As elsewhere, pumas are less likely to attack cattle, and probably proportionately kill more deer and smaller mammals than do jaguars. The range of body color in the puma at Descalvados was from a rather dark grayish brown to a decidedly red brown tone.

The ocelot or "jaguaterica" (*Felis pardalis brasiliensis*) is probably the most persistent hunter of the smaller mammal and birds of the pantanal. It is at least partly diurnal in its hunting, as trails picked up any time in the day were fresh and soon led to this most beautiful of the smaller cats, which climbs with the greatest facility.

We did not encounter the interesting dichromatic yaguarundi cat (*Felis yagouaroundi*) or the very rare bush cat (*Felis pajeros braccatus*), which latter was described by Cope from H. H. Smith's collection and still remains one of the scarcest cats in scientific collections. Both species are known to occur in the pantanal.

The common wild dog of the Rio Paraguay campo is one of the forms of the crab-eating dog or "lobito," which is widely distributed over much of Brazil and adjacent countries to the south and southwest. It is a short-legged, dark, fox-like dog, which runs with great speed. The most unusual of the wild dogs of this portion of South America and one of the most distinctive in the world is the red or maned wolf (*Chrysocyon brachyurus*), the "lobo vermelho" of the Brazilians. This long-legged, great-eared animal suggests a gigantic, stilt-legged, short-tailed edition of the red fox. The very slender legs are black, as is the muzzle, while the general body color is a fox red. The hair along the back is rather long, suggesting a mane, and the short, poorly brushed tail gives an impression that the job of constructing a very striking animal was left unfinished. An interesting parallelism is that the marked coloration of this species and that of the large swamp

deer, living in the same territory, are very similar. However, this strange dog apparently feeds on small mammals and to some extent on wild fruit, such as the small figs of the figueiras. The experience of our party with the single one collected shows that the red wolf is a savage fighter when brought to bay, fully able to hold its own against hounds.

Two species of otter occur in the Rio Paraguay at Descalvados, the smaller (*Lutra paranensis*), called "lontra," the larger (*L. brasiliensis*), the "areinha." The latter species has been considered to be generically distinct, as it has the tail distinctly flattened, with a ridge on each side. It is one of the largest otters known, and in total length is sometimes but little short of six feet. This giant species, which ranges through much of South America to the Rio de la Plata, will sometimes be found in the Rio Paraguay in small family groups, engaged in the graceful gambols for which otters are noted.

The Procyonidae is represented by the red coati (*Nasua nasua solitaris*) and the crab-eating raccoon (*Procyon cancrivorus nigripes*). The former is more likely to be encountered in the forest areas, while the raccoon is probably more partial to the truly riverine section. Both are often tamed and make interesting pets. Dogs find the coati a formidable opponent on account of its triangular canines, which are capable of serious injury to a dog as large as a foxhound, as one of our animals learned.

A black species of howling monkey (*Allouatta caraya*) and a capuchin (*Cebus azarae*) are frequent in the forested areas, particularly along the river. The howlers, which show sex-correlated dichromatism, are often heard at night, or even on gray days. The members of the expedition made a brave effort to rear several half-grown howlers, but with the failure usually encountered in such attempts with these delicate monkeys. They were thoroughly tame and most likable and interesting pets, with their quiet, dignified manners and solemn mien, so in contrast to the rowdy capuchins in our menagerie. The howlers were never mischievous and could be allowed to roam free, returning at night, from their diurnal wanderings over paling fences and compound trees, to the comfort of their open cage. They soon made friends, and would confide their face-wrinkling worries in low but deep and throaty complaints. The slower action of the howlers was always evident when they came within reach of the chained capuchins, and a rough-and-tumble immediately developed.

The tapir (*Tapirus terrestris*) is usually considered to prefer the general neighborhood of water, and will often spend part of his time in it, while in such situations water plants form at least part of his food. In the Descalvados area, however, tapirs are some-

FIG. 13. JABIRUS (*JABIRU MYCTERIA*) ON NEST

THIS NEST WAS LOCATED IN THE RIVERINE FOREST AND A SERIES OF MOTION PICTURES OF THESE BIRDS WAS TAKEN FROM A VANTAGE POINT IN ANOTHER TREE. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

times met considerable distances from permanent water, feeding on wild fruit. An adult female secured by the expedition in the riverine forest weighed 459 pounds. While the Brazilian tapir is undoubtedly an ancient type, it has retained its specific characters unchanged over a considerable territory, as it ranges from Colombia and the Guianas to southern Brazil, Paraguay and northern Argentina. Why this species, or a near relative of it, should occur in the North American Pleistocene, and not the Central American genus *Tapirella*, where *Tapirus* does not occur, is not known, but is one of the many instances in which the differentiation of the life of Central America from that of the continents to the north and south of it is marked.

Of the deer of the pantanal the most conspicuous are the "veado" or pampas deer (*Blastocerus bezoarticus campestris*) and the "ciervo" or swamp deer (*Blastocerus dichotomus*). The first of these is distinctly smaller than our eastern Virginia deer, the buck with light, graceful antlers, and both sexes capable of speed and agility which suggests a jack rabbit, with the "sky hop" of the latter, probably for better observation. It is abundant and partial to the open grassy or park-like campo, while the "ciervo" is more truly a species of the wet pantanal. In size the latter is large and heavy bodied, equalling a large mule deer, in the male with symmetrical, well-spread antlers of the *Odocoileus* type, while the striking body color has been mentioned under the red wolf. In contrast with the active little veado, the ciervo is slow and confiding. Only when thoroughly frightened does it seem to realize that another neighborhood may be safer. In consequence, it is killed in numbers for its hide, which, however, brings but a pittance. Apparently this beautiful species will soon disappear from lands where it is to-day the largest deer and one of the most beautiful members of its family.

Both types of peccaries are encoun-

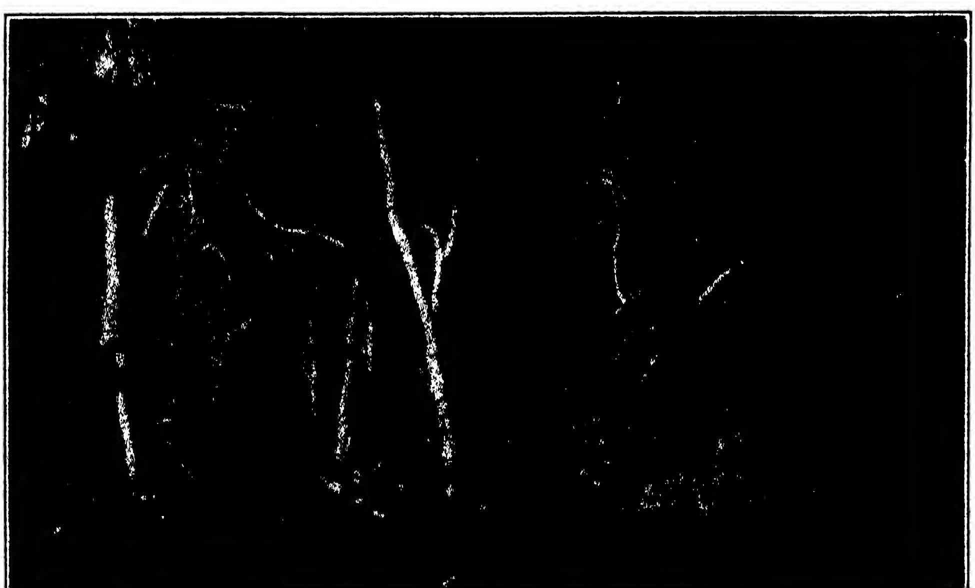


FIG. 14. JACARES (*CAIMAN*) ON THE BANK OF THE RIO PARAGUAY. THIS PICTURE ALSO GIVES AN IDEA OF THE DENSITY OF THE RIVERINE FRINGE FOREST. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

tered in the Descalvados area, the larger white-lipped species or "teschado" occurring in herds of up to a hundred or more, while the smaller collared species is usually in groups of from three to a dozen or so. The larger white-lipped peccary is always treated with caution, as it is a truculent pig, prone to charge if pressed too closely and capable of seriously injuring the hunter. Native dogs respect it and Indian hunters are careful in approaching the fortunately infrequent larger herds. The smaller collared species when pursued often takes refuge under partially uprooted trees or in similar places. When running for cover it can make surprising speed, bouncing along in a rabbit-like bolt. At bay, if pressed too closely, it can use its triangular canines with deadly effect, as many dogs have discovered. The collared peccary is more frequently seen than the white-lipped peccary, and is closely related to the forms found in Texas, New Mexico and Arizona.

Of the numerous rodents the capybara (*Hydrochoerus capybara*) is the most evident and interesting. This largest of the gnawing animals seldom wanders far from permanent water and is frequently found in groups, peacefully feeding or taking a sun-bath, close to the relative haven of the river or a corixo. The jaguar seems fond of capybara, while jacarés probably account for a number, but the modern demand for hides is apparently a greater factor in steadily reducing the number of these quaint and highly specialised rodents. Few of these are as truly water-loving as the capybara, which, with his truncate muzzle, small eyes and ears, deep body and pig-like bristles, seems to have been constructed of odds and ends. Agoutis (*Dasyprocta*), those slender-legged and active relatives of the guinea-pigs, were occasionally located by the dogs, but seldom seen otherwise, as they are chiefly nocturnal and exceedingly swift in their movements as they dash for safer cover. The tree porcupine (*Coendou*), the tropical American counterpart of our Canada porcupine, is infrequently encountered in the forest areas along the river, its prehensile tail added evidence that this feature has been a survival factor in many of the Neotropical mammalia.

Of the bats of the Rio Paraguay one proved of particular interest. The great false vampire (*Vampyrum spectrum*), the largest American bat, has a wing spread of over two feet. It apparently is not a common species and is also relatively rare in collections, although it has been known since before the days of Linnaeus. For many years it was considered to be a blood-sucker, and its technical name was given under this misapprehension. The true vampires belong to the distinct family Desmodontidae, and are much smaller species with highly specialized lancet-like incisor teeth. While several forms of the false vampire are now recognized, the species ranges from southern Mexico to Brazil. Nothing definite appears in the literature regarding the habits or food of this species. From my first acquaintance with museum specimens of the species its strongly developed canines always seemed out of place in a bat of frugivorous habits, such as those of many of its phyllostomatine relatives. A live specimen of this bat, which spread thirty inches across the wings, was captured by our party and placed in a cage. After it had eaten some finely cut beef, a smaller bat was placed with it. The false vampire promptly seized the smaller bat and, holding it with its wings, proceeded to devour it. Further experiments with *Vampyrum* were prevented by the death of the bat. Carnivorous habits have recently been reported as occurring in the related genus *Phyllostomus*, and the observations of our party show that at least two genera of

American bats share such habits with the Old World genus *Megaderma.* While the work of the true vampires was occasionally evident on our horses, no specimens of them were seen or taken.

No living edentates are more interesting and peculiar than the armadillos, of which three species, representing as many genera, were found by our party. The most outstanding of these, as well as the rarest, is the giant armadillo (*Priodontes giganteus*), or "tatu canestra." This, the largest of all living armadillos, measures as much as four feet, nine inches from nose to tip of tail, of which the powerful, tapering tail occupies over twenty inches. The largest digging claws of the front limbs are more than four inches in length. Its very large tunnel-like burrows are occasionally seen, but the animal is considered rare by all the native hunters. We managed to secure three, two alive, hoping to bring them to the United States in that condition, which I believe has never been done. Unfortunately, one escaped and the other, after feeding satisfactorily for a month, refused food and starved itself to death. One of these captives gave us an excellent illustration of the speed with which this most powerful of all American digging animals can bury itself out of sight. When but a few feet in its tunnel, the efforts of several men pulling on its tail were not sufficient to dislodge it or even seriously slow up its excavation work. This glyptodont-like genus is known to range from north central Argentina northward across eastern Bolivia and adjacent south central Brazil. Any promising young mammalogist, who wishes a unique experience in the preparation of material, should skin and skeletonize a giant armadillo. He will learn that for the size it can supply an unbelievable amount of hard work and tax his resourcefulness to an unequalled degree. The primitive Borero Indians prize the largest digging claws, which are used in pairs to make one of their most distinctive types of neck pendants.

Two ant-eaters are regularly encountered in the Descalvados area, the great ant-eater or ant-bear (*Myrmecophaga tridactyla*), the tamandua bandeira of the Brazilians, and the smaller tamandua ant-eater (*Tamandua chapadensis*). The former, with its strange build, very elongate head and broad brush-like tail, is not rare in the pantanal, living largely on termites, the hills of which it is able to open with its powerful fore claws. When frightened it lopes away with a peculiar rocking-horse gait, its great bushy tail going high with each drop of the fore quarters. Jaguars occasionally kill the great ant-eater, but the latter can defend itself most valiantly. Settling back on its hind quarters it delivers slashing blows with its fore limbs, which are armed with four-inch claws that cut like scythes. Probably only a jaguar hard pressed by hunger takes such risks, as these combats have been known to end fatally for the cat as well as the ant-eater.

The smaller tamandua is arboreal, its prehensile tail making it quite at home in that habitat. It is not uncommon and was brought to us alive by natives a number of times. One half-grown one became a most likable pet, with complete freedom of all our quarters, but radio battery acid proved too much for its innocently inquiring tongue. It fed most contentedly on the termites in chunks of their structures which were demolished for the purpose. Assiduously the pieces were gone over, and few termites escaped attention. This peaceful animal was never known to make a sound, until one day a captive young crab-eating dog nipped it; then our placid pet reared on its haunches, and with several lightning-like slashes drove the dog away, while in a high-pitched squealing voice it bid defiance to its assailant.

One of my unforgettable memories is

of the water birds on the Rio Paraguay at the end of the wet season. For variety and abundance they far surpassed anything I had previously experienced. Later in the dry season, when the completion of other work enabled me to turn my attention more to water birds, the abundance and variety was by no means so great. The local explanation is that the birds follow the receding water down the Paraguay. How true this is I do not know, but the abundance of early June was greatly depleted by early September.

The vast flocks were made up of many species, chief of which were wood ibis (*Mycteria americana*), egrets, group of roseate spoonbills (*Ajaja ajaja*), crying ibis (*Molydophanes caerulescens*), and most conspicuous and noteworthy of all the jabirú (*Jabiru mycteria*) or "tuyuyu" of the Boreros. This, the largest of American storks, stands as much as four feet high, snow white with the bare skin of the neck and head black, except for a collar of red or pink at its base, this color covering a gular pouch capable of marked inflation, particularly on the sides of the neck. The crown of the head bears a thin tuft of white hair-like feathers, which at close quarters adds to the ancient and dignified appearance of the bird. The bill of the jabirú curves up slightly in the end half. The jabirú nests in tall trees in the caapões or in an occasionally isolated one in the campo, constructing a huge structure, which is apparently added to year after year. Occasionally the community nesting "catita" parrots (*Myiopsitta monachus cotorra*) use the lower part of the jabirú's nest for one of their colonies. The young jabirú number two, and were still in the nest in August, solicitously tended by their devoted parents, although they were of quite fair size.

Wood ibis (*Mycteria americana*) were in very great numbers, as late as September often feeding by dozens in wet spots in the pantanal. The great cocoi heron (*Ardea cocoi*) frequented the riverine areas, along with the boat-billed heron (*Cochlearius cochlearius*), the night heron (*Nycticorax n. naevius*) and the most beautiful of the Paraguay herons—*Pilherodius*. Along the waterways anhingas or snake birds (*Anhinga anhinga*) were abundant, and the Brazilian cormorant (*Phalacrocorax olivaceus*) or "vigua" quite general, while the strange jacanas were much in evidence, running over river vegetation. The wild Muscovy duck (*Cairina moschata*) and several species of tree duck (*Dendrocygna*) were in numbers, the former particularly on the wet pantanal, flying up into trees when disturbed, but apparently passing much of their time in such situations. As the river sandbars became exposed a wealth of sandpipers, plovers and many skimmers (*Rhynchops nigra intercedens*) tenanted them temporarily.

On the dry pantanal the rhea or American ostrich was clearly the most interesting bird. It was usually met in small groups, generally in open treeless campo. It is to be hoped that the fate which in Argentina has overtaken this interesting genus of ratite birds will be prevented in southern Brazil, and that there it may be protected from the devastation of the feather-duster trade. Perhaps vacuum cleaners may be the rhea's salvation. Rheas can hardly be considered attractive from the standpoint of food, as their natural muskiness alone is unpleasant in the extreme. Their eggs are used as food by the natives and make a most acceptable omelet. The anomalous seriama (*Cariama cristata*), the sole representative of a family of debated relationship, is another most interesting campo inhabitant, as much an enemy of snakes as is the African secretary bird, which the seriama so much resembles. The turkey-sized screamer (*Anhima cristata*) perches on the top of some conspicuous tree and vocally advertises its presence.

The most brilliant of the conspicuous

land birds of the pantanal is the great hyacinthine macaw (*Anodorhynchus hyacinthinus*), the largest of American parrots, which, always in pairs and in groups of up to sixteen, raucously defies you and warns the entire district of your presence in their territory, as flying quite low, within gun shot, they circle above you again and again, until apparently tired they retire to some tall caapõe tree to talk it over among themselves.

Several other species of macaws, three of Amazon-type parrots and four species of parrakeets of several genera are regular in the pantanal, and all but one were seen by our party. Toucans of two genera (*Rhamphastos* and *Pteroglossus*), woodhewers of many types and ant thrushes of varied character, the glorious-voiced oven birds (*Furnarius*), and tanagers, finches, orioles and flycatchers of many genera made up a large part of the marked variety of the smaller land birds. A robin-like *Planesticus* suggested home, while at the next turn a gorgeous manakin dispelled that allusion. Contingas, however, were not seen, while swallows were not numerous in species. Woodpeckers were infrequent, but three species of kingfishers were abundant on the river, and a beautiful jacamar (*Galbula rufo-viridis*), very tame and confiding, was common in the open dry scrub forest.

The curassows were represented by quite a few species, one a great turkey-like *Crax,* while but two species of owl were seen, one a *Bubo,* the other a tiny *Glaucidium.* Of the hawks and the caracaras the variety was large and ranged from a tiny falcon smaller than a sparrow hawk to great brick-red hawks, but little smaller than some eagles. The everglade kite (*Rostrhamus sociabilis*), with its snail-eating habits, found much to feed upon in the literally millions of stranded *Pomacea* snails, left on every hand by the retreating flood waters.

About our headquarters the beautiful red-headed Brazilian cardinals of the genus *Paroaria* were abundant and trustful, while barn owls (*Tyto alba tuidara*) nested in the roof of the church at Descalvados.

The most abundant and evident large animal along the Rio Paraguay is the jacaré or caiman of that district (*Caiman* species). While not reaching the great dimensions of some of the species of Old World crocodilians, it makes up in numbers for its mediocrity in size. While the average adult is probably about eight to nine feet in length, they occasionally reach as much as twelve feet or even more. Doubtless jacarés are exceedingly destructive to all wild life as a whole, and are also responsible for the death of many cattle, particularly calves. Humans are not immune to their attacks, although they are not as generally dangerous to man as the African crocodile. Many men, however, have been maimed by them, and one of our party was seriously bitten in the foot by a jacaré while tramping in flooded pantanal. With them and piranhas as abundant as they are, swimming in the Rio Paraguay, or for that matter venturing in the larger areas of water any more than necessary, is not without perils.

Jacarés like crocodiles use sand-bars as sunning places, but also pull out on narrow bank shelves in the river forest. Often as many as a dozen will be found distributed along a short piece of river bank, but a foot or two above the water level. They are then quite sluggish and frequently several shots can be fired before the last survivors slide into the water. When in repose on land the head is kept raised, while in walking they raise themselves upon their legs and carry the body clear. Above in discussing the jaguar I have mentioned the extent to which jacarés spread over the pantanal when the latter is flooded. The Boreros eat the tail of the jacaré

after removing several long tendonous muscles.

Almost no lizards were seen at Descalvados during the dry season, and no chelonians except the great Brazilian land tortoise (*Testudo tabulata*), which was often encountered when hunting. The Boreros insist there are two species, one of which is very rare and much larger than the other. These animals, like armadillos, are regularly eaten by them. Armadillos are roasted whole, usually on a spit across the fire.

Of snakes the one most frequently brought to our attention was the rattlesnake or "cascavel" (*Crotalus durissus*). This is not at all scarce in the drier campo areas. The *Lachesis* type of pit vipers are also well represented, apparently by several species. We saw but few of these, possibly on account of the season. One of our hounds was bitten in the jowl by a poisonous snake, which was not seen. The two oozing punctures were soon surrounded by a rapidly augmented swelling, while the animal whined in pain. A prompt application of polyvalent antivenin had marked effect in ten hours, and the dog fully recovered in several days.

Few non-venomous snakes were seen except the anaconda, which locally is known as the sucuré. In size it does not reach Amazonian dimensions, the average individuals being not over ten feet in length. One large all black snake, possibly the famous mussurama, the foe of Brazilian venomous snakes, at Santa Rosa, not far from Descalvados, made an entirely unprovoked attack, coming for a considerable distance directly toward me, carrying the anterior part of the body well elevated. Just as I felt it would be necessary to stop the attack with a load of shot, the snake suddenly swerved, and sweeping about me disappeared in a hole in the ground. Two Indian boys who were with me fled, but returned to help locate the attacker, who, however, declined to leave his retreat. This snake was not less than eight feet in length. It reminded one, of course on a far larger scale, of the way our black snake will occasionally attack, but the Santa Rosa charge was without incentive, and my first knowledge of the snake's presence was its swift advance.

The fishes of the Rio Paraguay have furnished the subject for a number of the classical papers of Cope, Eigenmann and others. Needless to say, this fauna is tremendously rich in species, particularly of the highly specialized Characinidae. Even with all the previous work which had been done, the modest series of fishes taken by the expedition added four new species to science. Many of the fishes of the Rio Paraguay would be extolled in the highest terms for their angling qualities if they were better known and their habitat more readily accessible. Members of our party who were proficient with rod and reel had many experiences which would have made a salmon fisherman envious. The beautiful "dorado" (*Brycon hilari*), which is colored somewhat like, but far more brilliantly than, our striped bass, and fights with all the ability of a salmon, is common and runs from about six to nearly twenty pounds. The deep-bodied pacus (*Myleus*), which run to even greater weight, are just as powerful. The strange wolf fish (*Rhaphiodon typicus*), like the others a highly specialized characinid, possesses a pair of needle-like teeth at the end of the lower jaw, which lay over the face when the jaws are closed. In appearance and actions the wolf fish makes one think of a barracuda. The jaws of these fishes treat the angler's tackle much as a steel trap might, but if the leader and hook hold the fisherman will have all the thrills he can ask. The omnipresent piranhas (*Serrosalmus, Pygocentrus* and *Pygopristis*) are the fish menace to vertebrate life in Neotropical rivers. Much

has been written about them, probably many overstatements made, but they are undoubtedly the most justly feared existing fresh-water fishes. Whether their attacks are diverted or encouraged by agitation of the water remains unsettled, but there can be no question that a wounded or disabled man or beast falling into their home waters is frequently attacked and, unless able to get out of their reach, soon devoured or at least seriously injured. The taste of blood in the water seems to be the chief cause of their prompt concentration at any given point. I often have set afloat the skinned bodies of birds, and generally in an incredibly short time the piranhas were at them. In the ferocity of their attack they would sometimes leap clear of the water. In but a few minutes bones alone remained, when the bodies were moored so that results could be noted.

Piranhas do not readily take a hook, but when they do their triangular interlocking teeth play havoc with tackle. We trapped many in a cage trap, and used them for food. Captive young jaguars were frequently fed on them, and it is probable that, under certain circumstances, they may constitute part of the varied natural food of these cats. Piranhas must be stunned or killed by a blow before being handled. They are very tenacious of life, and if laid in the bottom of a canoe, without this precaution, they are able to vault their bodies into the air, and snapping teeth are thus a constant menace as long as life lasts.

The two most striking fresh-water mollusks of the Paraguay at Descalvados are *Pomacea insularum* and *Marisa planogyra,* the latter described from the expedition's collections. The dead shells of both literally pave great areas of the pantanal, particularly those sections which are more deeply inundated during the flood period. I have seen few living ones of either, stranded or in very shallow water, and it is difficult to secure living material, at least in the dry season. Most of the dead *Pomacea* have been punctured, apparently by the Everglade kite, which feeds upon mollusks. Few more remarkable resemblances exist than that between the adult *Marisa planogyra* and our well-known fresh-water genus *Planorbis.* I presumed I was collecting a very large *Planorbis,* which genus I know in our home streams. My colleague, Dr. Pilsbry, soon pointed out my error and showed me the ampullaroid type young. The flattened spirals of the adults may be nearly an inch and a half across. The bivalve mollusks were represented by the genera *Anodontites* and *Diplodon,* while doubtless numerous others would have been secured if time had permitted extensive search. Few land mollusks were noticed in the dry season, except for the large pink-lipped, white *Strophocheilus intertextus,* which was found dead in dense dry caapões. Living adults were probably safely hidden from the withering effect of many weeks of sizzling drought.

The dry season insect life was very scanty, being but an infinitesimal fraction of that I have found elsewhere in the American tropical and subtropics in the wet season. That the pantanal is rich in the wet season we know from the work of H. H. Smith at Corumbá. In the dry season there was not a single night producing the rich and varied flights of moths so frequently seen during the rains, but an occasional lone individual coming to our electric lights, the only illumination for many miles. Diurnal insects were inconspicuous and few, except for a limited number of small beetles and bugs. Wasps and bees were rare, except for colonies of the interesting black stingless bees *Trigona.*

Ants and termites were, of course, as generally evident as elsewhere in the tropics. The structures of the termites dotted many parts of the pantanal, par-

ticularly the campo areas. In height they reached as much as twelve feet, and in such cases were always slenderly conical and never domed.

The stridulating Orthoptera were little evident, although certain Acrididae were to be found in the dry campo, in open woods and the tall cover of wet pantanal—in the latter of the elongate type adopted for clinging close to a stem. A rough and shagreenous grasshopper of the genus *Ommexecha* preferred the dry ground of roads and trails, while equally protectively colored *Diedronotus* hopped among the fallen twigs of bush cover. The strange proscopid grasshopper *Cephalococma,* which in its elongate form superficially suggests the walking-stick phasmids, was occasionally encountered in low bush, which also is the preferred habitat of many of its near relatives.

We have heard of the plan for keeping parts of Africa as permanent preserves to show the future what Africa was when white men came—how truly it is the Pleistocene carried on into our day. There is no fauna, except possibly that of Australia, more unique and distinctive than that of the Neotropical region. There are few places where this strange and ancient life remains as little disturbed and as readily seen as on the pantanal of the upper Paraguay. It is perhaps hoping too much that efforts may be made to conserve some of this wild land before the interesting mammals and birds, as well as other forms of the more conspicuous life, have been reduced to the vanishing point.

In the pantanal of the Paraguay we truly have the Neotropical vertebrate fauna more fully and abundantly represented, and by its most distinctive types, than in any single area of the lowland forests of South America.

MATHEMATICS DEVELOPED BY THE COMMON PEOPLE

By Professor G. A. MILLER
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A STRIKING instance of the development of mathematics by the common people is the adoption of our common number system to the base 10. This is commonly assumed to be due to the fact that in early times people counted by means of their fingers and hence it has apparently no connection with the suitableness or the unsuitableness of the number 10 for this purpose. It is necessary to bear in mind the influence of the common people in the development of mathematics in order to explain such recent observations as the following: "I have tried, in other fields, to show the incredible confusions, of which the whole world is now one seething example, that followed from the invention by the Hindu mathematicians of negative quantities, and their justification from their analogy to debt."[1]

A part of these confusions are due to the fact that when negative numbers are used we have to admit that the ratio of a smaller number to a larger number can be the same as the ratio of a larger number to a smaller one, as results from the equation $-1/1 = 1/-1$. We have also to admit that a number can be less than zero, and hence that there are things which can be regarded as less than nothing. It is clear that as long as only positive numbers were used it seemed logical to say that the ratio of a smaller number to a larger one is always less than the ratio of a larger to a smaller, and that zero is the lower limit of the real numbers. Mathematicians naturally abandoned these views reluctantly, and even during the latter part of the eighteenth century there were some who argued that the use of negative numbers should be abandoned, since they seemed to lead to erroneous conclusions. The people, however, continued their use in view of the many advantages which this use presented, notwithstanding the fact that a clear theory of these numbers was then still lacking.

The use of negative numbers preceded a satisfactory theory thereof by many centuries and it now seems unlikely that the Hindu mathematicians contributed anything towards the establishment of this use in Europe. It is more probable that the European mathematicians began to use these numbers independently and later developed a theory which justifies this use. The Hindu mathematicians, however, deserve the credit of having used these numbers before they are known to have been used elsewhere, but their work along this line is not known to have had any effect on the later developments by the Europeans. In particular, the Arabs, who transmitted much of the early mathematical knowledge to Europe, did not adopt the negative numbers of the Hindus. In a certain sense negative numbers forced themselves on the attention of mathematicians in view of the simplifications which their use made possible and they therefore present a very interesting feature of the development of our subject.

It is well known that the ancient Greek philosophers at first considered it desirable to restrict the number concept to positive integers which exceed unity, as is illustrated by the following definition: "A number is a multitude of

[1] F. Soddy, "The Interpretation of the Atom," preface, 1932.

units."[2] This view was supported by such eminent philosophers as Plato and Aristotle. Notwithstanding the eminence of its supporters, it was gradually abandoned by various Greek writers who found it convenient to include unity among the numbers even if it has fundamental characteristic properties which led many others to regard it as the source of all numbers but not as itself a number. In particular, Theon of Smyrna (about 130 A.D.) asserted that unity is not a number, but soon thereafter he included it among the odd numbers as well as among the natural numbers.

This inconsistency on the part of Theon of Smyrna is typical of certain mathematical developments relating to questions in regard to which eminent authorities pointed one way and actual applications by the common people exhibited an easier way from the standpoint of these particular applications. Not only did unity thus secure an entrance into the number concept, but this concept had to be extended so as to admit the rational fractions, the irrational numbers, zero, the negative numbers, and finally the complex numbers. In fact, unity and the rational fractions had been accepted as actual numbers long before the ancient Greek philosophers endeavored to exclude them for the sake of securing thereby a simpler philosophical theory. The development of mathematics has frequently been dominated by the use made of it by the common people and not by the theoretical considerations advanced by the philosophers. The theory had at times to accommodate itself to the uses, since the uses failed to accommodate themselves to the proposed theory.

The late Felix Klein (1849–1925) expressed the influence of some such uses in the following words: "We have repeatedly emphasized what an important part in the development of the science has been played by the algorithmic process, as a quasi-independent, onward-driving force, inherent in the formulas, operating apart from the intention and insight of the mathematician, at times, often indeed in opposition to them. In the beginnings of the infinitesimal calculus, as we shall see later on, the algorithm often forced new notions and operations, even before one could justify their admissibility. Even at higher levels of the development, these algorithmic considerations can be, and actually have been, very fruitful, so that one can justly call them the groundwork of mathematical development. We must then completely ignore history, if, as is sometimes done to-day, we cast these circumstances contemptuously aside as mere formal developments."[3]

The algorithms connected with the solution of the algebraic equation constitute one of the clearest illustrations of these remarks. Some writers have expressed the view that even the ancient Babylonians, about 2000 B. C., observed that some quadratic equations have two roots, and hence that equations which explicitly involve only one unknown may actually involve more than one. No instance is, however, yet known where it was explicitly stated before the beginning of the Christian era that a given algebraic equation is satisfied by more than one number and hence may yield more than what was explicitly put into it. While the ancient Babylonians solved certain quadratic equations according to the modern formulas and made some progress in the solution of cubic equations these algorithms remained fruitless as regards the extension of the number concept not only in their hands but also in the hands of the an-

[2] Book VII, Euclid's "Elements."

[3] "Elementary Mathematics from an Advanced Standpoint." Translated into English from the German by Professors E. R. Hedrick and C. A. Noble, University of California, Vol. 1, page 79, 1932.

cient Greeks during their golden period of mathematical development at the time of Euclid, Archimedes and Apollonius.

The first fruits as regards the extension of the number concept to which the solutions of quadratic and cubic equations contributed largely relate to the irrational and the negative numbers. It has recently been established that the theory of the former, which was developed by Eudoxus (about 410–356 B.C.), differs only formally from the modern theory, commonly known as the Dedekind cut. This theory has a remarkable history, since it constitutes probably the only instance in the history of mathematics where a sound doctrine was abandoned for two millenniums because it was opposed by one man. In the present case it was Aristotle who used his strong influence so successfully in opposition to what appears to us now as a satisfactory doctrine of irrational numbers, but his influence could not deter the common people from using these numbers without a satisfactory theory therefor, just as they used negative numbers for a long time before the development of a satisfactory theory relating thereto.

The late H. Poincaré stated in an address read at the Rome international mathematical congress, 1908, that "mathematics is the art of giving the same name to different things." For instance, the number concept originated from the counting of similar objects, but it was extended in prehistoric times to the counting of dissimilar ones, as is illustrated by the fact that in the ancient Egyptian Rhind Mathematical Papyrus (between 1788 and 1580 B.C.) such different objects as houses, cats, mice, etc., are added and that a special word for the abstract unit appears therein. This primitive counting origin of the number concept is very different from the modern concepts of irrational and complex numbers, which have no direct connection with counting. If the question is asked why the mathematician uses the same name for such different concepts and thus in a certain sense has brought "incredible confusions" into his subject, it should be noted that the confusions would have been still greater if he had failed to follow here the pragmatism of the common people. The common properties of the different kinds of numbers have been found to outweigh their diversities in actual applications. This was not the discovery of a few men, but the resultant of tendencies which were frequently conflicting and denounced.

The philosophers have done much towards establishing order in mathematics, but they have been most successful when they followed the lead of the common people. When they tried to limit the number concept, as the ancient Greeks did, they hampered the onward march of mathematical progress instead of contributing thereto. It is only natural that the devotees of this subject have at times been perturbed as regards its future. Already in 1869 H. Hankel was led to compare mathematics with the Tower of Babel because the mathematicians speak such different languages, and in an addendum to his well-known "Erlanger Programm," Felix Klein remarked that the extensive confusion of languages in mathematics appears to have a serious but undesirable tendency towards the self-blocking of all mathematical progress. Fortunately, such unifying and clarifying notions as functions and groups tend to simplify the mathematical language and also to embody experiences of the common people.

The ancient Greek term "geometry," which is etymologically equivalent to our modern term surveying, exhibits that the practical needs of the common people contributed towards the development of this large branch of mathematics. Recent discoveries relating to ancient

Babylonian mathematics show that the intellectual needs of these people made themselves felt in very early times, since they include geometric problems which seem to imply a knowledge of the so-called Pythagorean theorem long before Pythagoras was born. In fact, the oldest extant Babylonian mathematics is largely pure mathematics and shows that the mathematical interests of the people, even in those early times, were inspired by a desire to understand the nature of imaginary situations which are not likely to arise in practical life, including the use of such a large number as $195\,955\,200\,000\,000 = 60^8 + 10.60^7$. It is a great mistake to assume that the common people have been interested only in applied mathematics. The history of the pre-Grecian civilizations seems to imply that they were, however, not much interested in rigorous proofs according to modern standards.

The most important difference between the mathematics of the common people and that of the philosophers is that the former is based upon implied postulates, which are not necessarily independent, while the latter employs explicit postulate systems and aims to reduce the number of the postulates to a minimum. In both cases the correctness of the results depends upon the correctness of the postulates, and in both cases the confidence in the correctness of these results has the effect of producing a feeling that eternal truths are under consideration. The geometric developments of Euclid's "Elements," which are explicitly based upon a system of postulates, inspire no more confidence than the table of unit fractions which appears in the older Rhind Mathematical Papyrus, where no such system appears. The modern student of elementary mathematics who is inclined to reflect on the nature of these courses may be helped by bearing in mind that both the common people and the philosophers have had a share in providing the mathematical material with which he is confronted.

With the advent of printing mathematics as well as the other sciences became more and more enslaved to books, and the development of mathematics became more and more largely confined to those who studied these books. With the increase in the number of available books cooperation in the advancement of our subject became more efficient. One type of cooperation is represented by the mathematical societies, and it is interesting to note that the common people took an active part in the early organization of such societies. The oldest of these which has survived through more than two centuries is the "Mathematische Gesellschaft zu Hamburg," organized in 1690. During the first hundred years of the existence of this society the most learned mathematicians of those times failed to join it, so that its membership was composed largely of common school teachers, bookkeepers, merchants, etc. The great advances made during this period in the development of analytic geometry and the calculus were not due to members of this society and were not promulgated by them.

A noted early English mathematical society was founded at Spitalfields in 1717 and was taken over by the Royal Astronomical Society in 1845. This was at first little more than a workingman's club at which questions of mathematics and natural philosophy were discussed every Saturday evening. Each member present at a meeting was entitled to a pint of beer at the common expense, and it was the duty of every member who was asked a mathematical or philosophical question by another member of the society to answer the question to the best of his ability. The society accumulated a valuable library and its rooms became headquarters for

lectures on various scientific subjects. While it later included among its members some of the leading English mathematicians it is mainly interesting in the present connection in view of the fact that it was organized by the common people and exhibits the influence of these people on early organizations of mathematicians.

The secondary base 60 which appears in our tables relating to the measurement of time and of angles can be most easily explained in accord with the known historical facts by assuming that the ancients selected it in order to assist the common people to avoid the use of common fractions. The numbers $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, were commonly represented by the ancient Babylonians by 30, 20, 15, 12, 10, respectively. The primary base 10 is not well suited for the avoidance of common fractions, since even $\frac{1}{3}$ and $\frac{1}{4}$ do not appear as integers when this base is used. It is a very singular fact that the ancients failed to employ a symbol corresponding to our modern decimal point, which enables us now to avoid the use of common fractions. While every real number can be represented as an infinite decimal number, comparatively few of them can be represented as a finite decimal. Those which can be thus represented are, however, of special historic and practical interest. They obviously are equivalent to the common fractions whose denominators involve only powers of 2 and 5. The base 60 is much better adapted than the base 10 for the avoidance of common fractions, but even $\frac{1}{7}$ does not correspond therein to a finite integer when the point corresponding to our decimal point is omitted. Hence the modern student of mathematics naturally finds it difficult to explain the extensive use of the base 60 in ancient times and its persistence in our modern tables. Such difficulties point, however, to the influence of the common people on the development of our subject and provide material for harmonizing hypotheses.

One of the noteworthy features of the development of mathematics is that it has restricted the field of the puzzles, which have always interested the common people. The Indian mathematician Brahmagupta (born 598) is said to have remarked near the end of his algebra that "as the sun obscures the stars so does the proficient eclipse the glory of other astronomers in an assembly of people by the recital of algebraic problems, and still more by their solution." The hau or "aha" problems of the Rhind Mathematical Papyrus have sometimes been called puzzle problems, and it is probable that they were at first regarded as such, but they now may be regarded as linear equations in one unknown and hence they come under a well-known general algebraic theory. The first of these is problem 24 and reads as follows: "A quantity and its $\frac{1}{7}$ added together become 19. What is the quantity?" The puzzles presented by individual problems cease to be puzzles when it is recognized that they come under general theories and hence the development of mathematics tends towards the eradication of various puzzles which were sufficiently elementary to interest the common people.

While the sense of discovery has probably always furnished one of the most forceful inspirations for mathematical study, the growth of the mathematical literature naturally tends to make it more and more difficult to determine whether these discoveries are actually new and are not involved as special cases of a general theory. The common people are thus deprived more and more of the incentive furnished by the feeling that they can make actual contributions towards the advancement of mathematical knowledge. This is probably not the most serious obstacle towards the maintenance of their keen

interest in mathematics. The feeling that they might be regarded as ignorant if they expressed their views to those who enjoyed better advantages to become acquainted with what is well known is probably a more serious deterrent factor on the keen interest of the common people in advancing science. The difficulties involved in securing the necessary knowledge to understand the nature of the modern developments in comparatively new fields are naturally viewed with some misgivings by those who realize that the effectiveness of scientific knowledge depends largely upon a wide-spread understanding and use thereof. This is especially true of such a basic and abstract science as mathematics aims to be.

The influence of the common people on the adoption of tables of weights and measures and on the problems of commercial arithmetic is noteworthy. The Liber Abbaci (1228) of Leonardo of Piso is one of the most favorably known early works in which commercial problems receive much attention. The date of this work presents an unusually interesting question as regards the importance of being acquainted also with the secondary sources of historical information. The date on the extant MS is 1202 and the histories of mathematics which are now most widely used in our country give this date notwithstanding the fact that it has been proved that it can not be correct. The question is considered in particular, near the beginning of volume 2, M. Cantor's noted "Vorlesungen über Geschichte der Mathematik." It is, therefore, useless to cite the original source, as is sometimes done, to justify the use of the date 1202 for this particular work, and in this particular case it is more important to be familiar with the secondary sources of information than with the original, although the contrary is probably more commonly true if one can be acquainted with only one of these sources.

THE PLACE OF SOIL IN THE BIOLOGICAL COMPLEX

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SOIL science, as an independent discipline, is of rather recent origin as compared to other branches of knowledge. Before 1870 the study of soils was only more or less incidental in various other fields, such as chemistry, botany and geology. As geology became an established discipline with a growing body of information regarding the nature of rocks and with methods for studying rocks and their weathering products, scientists in this branch took some interest in soils. Many of these studies were fruitful, *provided that they were confined to a small area;* that is, in an area having essentially uniform climate, vegetation, age and relief, any differences in parent rock would frequently give rise to differences in soils. But these differences were difficult to interpret in terms of native or cultural plants.

It was observed that if a section were made through any soil it is made up of several layers, or horizons, called, collectively, the soil profile. And unlike the layers in a body of sediments, a genetic relationship exists between the horizons of the profile: they evolved together. It was further observed that whereas rocks occurred quite promiscuously all over the world, soil types were limited to rather definite geographical areas. Thus, for example, the Podzols, the Chernozems and the Laterites were found only in certain distinct climatic and biological regions. With the recognition of this definite element of geographicity of soils came the conception of soil as an independent natural body. The naturalist was now in a position to study the soil from an entirely scientific point of view without being restricted to practical investigations. Thus a new discipline arose about 1870—pedology.

From a consideration of this principle of geographicity there follow several important deductions regarding the influences in operation during the genesis of a soil. As the chief factors of climate are rainfall, temperature and relative humidity, it will be obvious that these influence the amounts of various chemical elements and compounds in the soil; and further, that any influences which bear upon these climatic factors will be reflected in the soil. For this reason it is clear that soils will be influenced by vegetation and relief which modify the conditions of moisture and temperature. And, as the process is essentially one of evolution, time will be important. As the cooling and moistening of the surface depend somewhat upon the nature of the underlying rocks, and as extremes in chemical and mechanical composition of the rocks will influence the salts in the soil, it is clear that the parent rock will need consideration. A graphic illustration of these factors could be shown thus: Soil = f (Climate, Vegetation, Relief, Age, Parent Rock).

THE DEVELOPMENT OF PARENT MATERIAL

The first step toward the development of a soil is the accumulation of parent material. Weathering proceeds under the influence of physical and chemical forces. The action of wind, moving water, ice and temperature changes act to disintegrate large masses of rocks. Under the chemical influence of water, carbonic acid and oxidation-reduction reactions the chemical composition of the

rocks is altered. Of course, some of these actions are going on in the soil, but here they are merged with other forces of greater magnitude. These chemical changes during weathering are quite similar under different climatic régimes, but external differences, especially temperature, determine the rate and the direction of the reactions.

The greatest mass of the mineral matter in rocks is composed of silicates and alumino-silicates. Such rocks as limestones contain, of course, the alkaline earth metals in the carbonate form, but most of the cations (*i.e.,* ions having a positive charge) exist in the rocks combined with silicic and alumino-silicic acids. Under the weathering processes these salts are hydrolyzed to form the alumino-silicic acid and the carbonate of the cation, thus:

$$K_2O \cdot Al_2O_3 \cdot 6SiO + 3H_2O \rightarrow 2KOH + 2H_2O \,.\, Al_2O_3 \,.\, 2SiO_2 + 4SiO_2$$
$$2KOH + H_2CO_3 \rightarrow K_2CO_3 + 2H_2O$$

The carbonates of iron and manganese are unstable and decompose to the oxides. By various interrelations many anions and cations combine to form other salts, such as sodium chloride, potassium sulfate and a host of compounds varying greatly in solubility. These are removed or are accumulated, depending upon the degree of moistening and the position of the water table. The weathering process goes on under essentially sterile conditions and should in no sense be confused with the formation of soil.

The Genesis of Soil

Some time after the accumulation of parent material there is an introduction of living matter. As respects soil, living matter presents two different aspects: (1) synthesis and (2) decomposition. For the purposes of general consideration there are two great groups of plants which synthesize organic matter, grasses and trees. Of those which decompose organic matter there are: (1) the higher animals, (2) anaerobic bacteria, (3) aerobic bacteria and (4) fungi.

The optimum conditions for the growth of these several classes of organisms vary widely between classes. Further, the different classes of micro-organisms which decompose organic matter give rise to quite different products. (Of course, the ultimate end products, where the processes go to completion, would be essentially the same: namely, carbon dioxide, water and ash; but the products found in the soil at any moment are quite different.) The organic acids, and their salts, produced through the activity of fungi, are quite soluble; while those resulting from bacterial action are relatively insoluble. Thus the two classes of micro-population have entirely different influences in the development of soil.

Before examining the influence of a biological community in the development of soil the nature of the colloids in the soil should be briefly considered. These colloids, which have been called the "protoplasm of the soil," are of two general types: (1) the inorganic, which constitute the fine portion of the clay, are made up of alumino-silicates resulting largely from the partial weathering of the feldspar minerals; and (2) the organic, which are chiefly composed of lignin and result from the decomposition of organic matter. These colloids absorb cations by the ordinary base exchange reaction, according to the relative concentration of the various cations present; and their properties vary enormously, depending upon which cations are absorbed. There are three principal types which may be designated as the hydrogen-colloid, the sodium-colloid and the calcium-colloid. In the absence of flocculating electrolytes the hydrogen-colloid is acid and easily dispersed into colloidal suspension; the sodium-colloid

is highly alkaline and is the most easily dispersed; while the calcium-colloid is mildly alkaline and remains in a flocculated state. Obviously, the first two can be easily leached from the surface soil, while the calcium-colloid will not be so leached. These mobile colloids may be flocculated in a lower horizon giving rise to a layer high in its percentage of clay. Such a layer, called the "B" horizon, is frequently indurated into a sort of sandstone in the case of the Podzol.

The Soil-building Processes

Depending upon the nature of the environment, there are three principal types of soil formation—calcification, podzolization and laterization. The calcification process is maintained under conditions of restricted rainfall. There is some leaching, but not enough to remove the carbonates of the alkaline earth metals and they accumulate in some horizon of the soil profile. The vegetation consists of grasses, or grass-like plants, which are heavy feeders on the bases, especially calcium. The prominent organisms are bacteria.

Under such conditions the plants bring bases from the lower to the surface soil in such large amounts that the colloids, both organic and inorganic, remain flocculated. The products from the decomposition of the organic matter by bacteria are relatively insoluble and remain in the upper part of the soil. It might be added then that this soil process conserves those elements considered as essential for the growth of crop plants. In the accompanying sketches are shown two important examples of soils developed under such conditions—the Chernozem and the Sierozem. The Chernozem is developed under conditions of sufficient moisture to give a luxuriant grass vegetation with the accumulation of a large amount of organic matter, while the Sierozem approaches the desert. Intermediate between these two are the Brown soils. The great wheat lands of the Americas and of Russia are found on the Chernozem and Brown soils.

The podzolization process of soil formation is dominant throughout the humid regions but especially in the more northern part. Here there is sufficient moisture to remove the soluble salts, both of the alkali and of the alkaline earth metals, completely from the soil. The chief vegetation is forest and the most prominent organisms are fungi. Forests are not as heavy feeders on bases as are grasses. In this respect there is a great difference between the coniferous trees and the deciduous trees. The conifers feed very lightly on bases, shed their leaves slowly and, due to their resinous nature, these leaves and twigs decompose more slowly than do those of the deciduous forest. Because of the toxic action of the tannins from the trees on bacteria and because of the low content of bases the fungi are more prominent and the products of the decomposition of the organic matter are relatively soluble.

As the trees do not furnish enough bases to the surface of the soil for the complete neutralization of the carbonic acid dissolved in the rain water, the base exchange colloids, both organic and inorganic, become saturated with hydrogen. In this condition the colloids are easily dispersed and are leached downward into the lower horizons of the soil profile. Further, the iron appears to be in the reduced form near the surface in the presence of the organic anions (*i.e.*, ions having a negative charge) resulting from the decomposition of the organic matter. This reduced iron moves downward in true solution, but as it passes out of the influence of the soluble organic matter it is oxidized and precipitated in the lower horizons.

Thus in the case of the Podzol developed under extreme podzolization, an entity entirely different from the Chernozem is produced, even from the

identical parent material. The surface of the Podzol has been impoverished of bases, nitrogen and colloids. The soil is highly acid throughout. Almost nothing but silica remains in the white, leached horizon near the surface, while a more dense horizon in which iron and alumina have accumulated underlies it. Naturally, such a soil is considered infertile for the ordinary plants cultivated for human food, even though it supports well a native vegetation that has evolved with the soil.

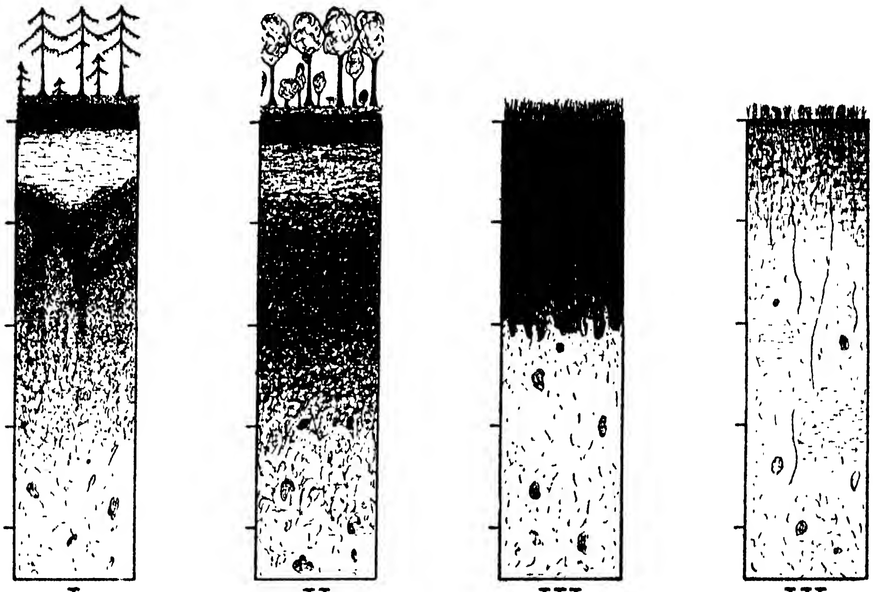
The great soil zone immediately south of the Podzol has been, until recently at least, the most important since the days of the old Roman Empire. Our present western civilization is largely developed on these Gray-Brown Forest soils. The climate is similar to that of the Podzol, except for the higher temperature. The forest is chiefly of deciduous trees. As the leaves are shed every year there is a greater mass of material deposited on the soil from these plants than from the coniferous trees; and further, the deciduous trees are heavier feeders on the bases, especially calcium, than are the pines and spruces. Thus, more bases are returned to the surface of the Gray-Brown Forest soils and they do not become as highly acid as do the podzols. Although these soils are developed under the same podzolization process, it is less intense and the surface horizons contain more organic matter and more nutrient elements. The soils are, of course, much less fertile for most crop plants than the Chernozem, but more fertile than the Podzol.

The laterization process, peculiar to the Laterite soils, is operative under the extreme moistening and high temperatures of the tropical climates. The weathering process under which the parent material accumulates is very intense. The hydrolysis of the minerals goes on very rapidly, such that the solution around the individual particles of mineral is neutral or slightly alkaline in reaction. Further, the vegetation grows and decomposes very rapidly, bringing bases to the surface in large amounts. Under the influence of this alkaline reaction the silica becomes soluble, especially the silica of the alumino-silicic complexes. But the iron and alumina are resistant and remain. Hence there is developed a parent material for soil, consisting largely of iron oxide and alumina with quartz silica, manganese and resistant compounds of less importance. After hydrolysis has gone nearly to completion, the bases are so depleted that further weathering results in an acid reaction in the soil. As soon as the soil becomes acid the podzolization process becomes impinged upon the material accumulated through laterization.

There may be said to be 13 of these great soil zones, of which 4 of the most important are shown in accompanying sketches. Each of these has developed under a particular set of conditions of climate, vegetation and relief. Further subdivisions within the group exist as a result of differences in age and parent material.

The Biological Complex

In the study of any phase of the landscape—plants, soil or animals—it is of the utmost importance to appreciate that the landscape has evolved as a whole. The present state of any soil, or of any other part of the landscape, represents an equilibrium between many forces. It is continually moving—dynamic. Any change in climate or vegetation immediately upsets the biological equilibrium and the system starts moving in the direction of another equilibrium point. Although the climate and vegetation are the most directly noticeable and, in general, the most commonly important phases of this biological complex of which the soil is a part, many less obvious features are important and may



	I Podzol	II Gray-Brown Forest	III Chernozem	IV Sierozem
Profile	A very thin organic layer lies on top of gray leached soil which is over a dark brown horizon.	A rather thin organic layer lies over grayish-brown leached soil which is over a brown horizon.	Black soil, grading into a whitish calcareous horizon.	Grayish soil, grading into lighter calcareous material.
Vegetation	Coniferous forest	Deciduous forest	Tall grass prairie	Short grass and desert plants
Climate	Cool Moist	Temperate Moist	Temperate to cool Semi-arid	Temperate to cool Arid
Fertility (crop plants)	Low	Medium	Very high	Medium to high if irrigated

Sketches of the Profiles of Four of the Great Soil Groups. These sketches show the great differences in the profile character of mature soils in equilibrium with different biological complexes and developed from identical parent material. Each section is 54 inches in depth.

change the entire procedure. Itasca Park in Minnesota can be cited as an example: This area was set aside by law to remain in the "natural state." The destructive works of fire and man were to be controlled and the area allowed to develop in a natural way as an example of the normal biological complex of the region. It was thought expedient, however, to destroy the wolves, which prey, not only upon the animals in the park, but also upon the live stock of nearby farms. Since the wolves were the natural predators of the beavers and the deer, these latter species have accordingly increased enormously. Competition for food among the animals has resulted in the destruction of the aspen trees near all the lakes and streams by the beavers and of the young pine reproduction by the deer. Such a change in vegetation has also, of course, upset the normal soil development in the area. This case has been mentioned merely to

illustrate the delicate balance which exists between various parts of the biological complex—the whole is one evolutionary complex.

Man himself is a part of this complex. Obviously man's activities upset the conditions which would exist in his absence. But if man is considered as any other organism, adjusting himself to his environment as best he can, then man is in a position fundamentally like that of any other organism of the complex. Considered in this light, the changes made by man are normal changes.

Of great importance to man are the adjustments which he himself makes according to the biological complex in which he finds himself. That the folk songs and other cultural attributes of man bear a direct relationship to the landscape in which they are developed is well known. In man's struggle for food and shelter, adjustments of far-reaching social consequences are made. Those plants which are grown for human food and for the food of domestic animals are rather limited. Naturally those plants and animals which most nearly approach the native organisms that formed a part of the biological complex will develop the best. The cereals may serve as an example. These grass-like plants are similar to the native grasses of the Chernozem, but they are very unlike the forest, especially the coniferous forest of the Podzol zone. It is said, therefore, that the Chernozem soils are more fertile than the Podzol soils. This is true only in respect to certain plants. Certain other plants, such as pine trees, find their best (most fertile) soil among the Podzols. Each of the great soil zones is most fertile for certain plants. But the plants which man raises for food are, for the most part, quite unlike those native to the Podzol, Gray-Brown Forest and several other of the great soil zones. Man must then alter the soil which is fertile for pine trees in order to grow other plants which he wants. But he need only plow the ground in the Chernozem and Brown soil zones. Other comparisons of like nature could be made regarding domestic animals and wood for fuel and shelter. As a result man constructs quite different economies and quite different social structures on the various soils.

It is, therefore, of the greatest importance that soil be recognized as one of the factors in the biological complex and studied from that point of view. It is a natural entity in itself, having its own special morphology and dynamic, and developing with the landscape of which it is a part. These various soil entities, produced through the sum total of the climatic and biological forces impinged upon them, have certain possibilities and certain limitations for the development of man. Like any other part of the complex man contributes an influence upon the complex and also he is fundamentally influenced by it.

THE DISPLAY OF WALLACE'S STANDARD-WING BIRD OF PARADISE IN CAPTIVITY

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CURATOR OF ORNITHOLOGY, U. S. NATIONAL MUSEUM

WHEN one finds a bird of unusual plumage combinations, very plain save for a localized brilliance of color or singularity of plume, the question arises as to how the bird utilizes its peculiarities in its display. It is obvious that the display is the chief, if not the only, opportunity for use of such characters as elongated plumes, bright gorgets, etc. Among all the birds of the world none are more abundantly supplied with plumage modifications of a purely display type than the birds of paradise, and among these remarkable creatures none is more bizarre or aberrant than Wallace's standard-wing.

The male Wallace's standard-wing is a dull earth-brown bird with a large brilliant emerald green pectoral gorget extended into a free V-shaped apex about five or six inches long on either side, and with two peculiar, whitish, narrow-webbed and terminally spatulated, erectile feathers on the upper surface of the carpal angle of each wing. (Fig. 1.) The female lacks the green gorget and the whitish plumes, and is wholly dull earth-brown. The species is extremely rare in captivity, and, as much of our knowledge of the displays of birds of paradise is based on observations of caged birds, it follows that little is known of the courtship poses of the present species. In fact, a search through the literature has failed to reveal a description of the display antics of Wallace's standard-wing.

The National Zoological Park in Washington is fortunate in possessing a splendid male of the Halmahera race

[1] Published by permission of the secretary of the Smithsonian Institution.

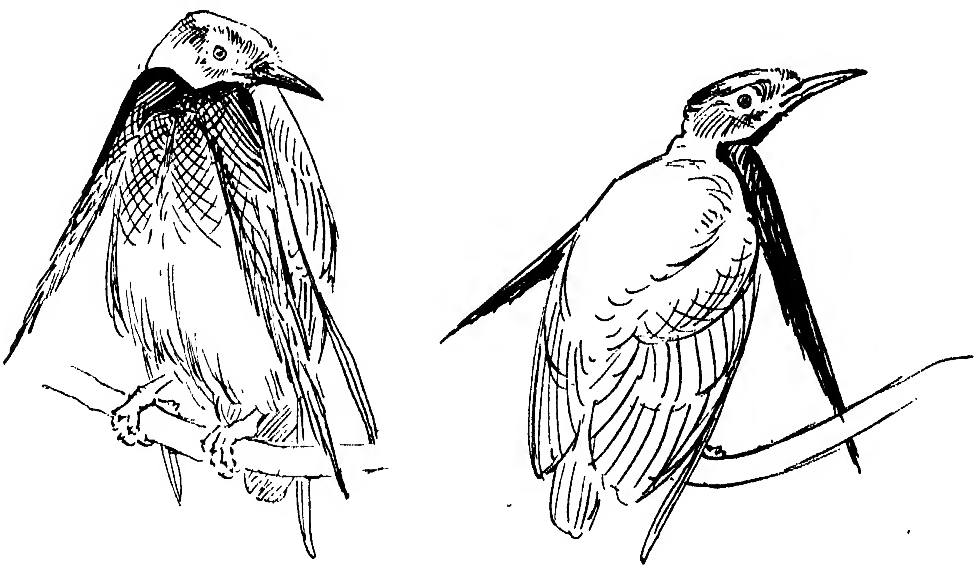

FIG. 1. RESTING POSTURE

of Wallace's bird of paradise (*Semioptera wallacei halmaherae*). This bird, which has lived there now for about two years and which is in good health and perfect plumage, was recently observed displaying. Mr. E. P. Walker, assistant director of the park, who was with me at the time, was as much surprised as I to see the way in which the bird displayed. I made several subsequent visits to the bird to get more detailed notes, and accelerated its activity by bringing with me a skin of a female and of another male from the museum and displaying them to the captive. Later Mr. R. Bruce Horsfall, artist of *Nature Magazine*, went out to the park with me and made the sketches which illustrate this paper. I am greatly indebted to Mr. Horsfall for his kindly cooperation.

My notes on the display may be summarized as follows.

The first indication of approaching display is a change in the posture of the bird. Instead of sitting in the usual semi-erect pose, it bends over forward or heads down a branch so that its head is lower than its body; sometimes even lower than its feet. (Fig. 2.) Then it gives a few harsh, rasping *tscharrrr* notes in rapid succession; then flaps its wings three or four times rapidly, the wings not more than half open at any time in the flapping. (Fig. 3.) After a few such wing beats, which, if the bird were sitting upright, would be quite comparable to the first beats of a grouse's wings (*Bonasa umbellus*) when

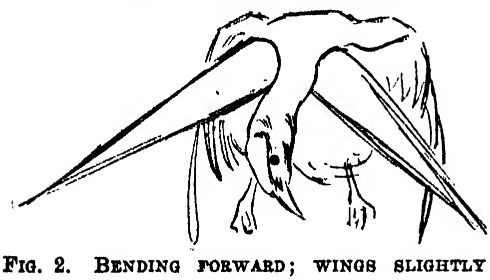

FIG. 2. BENDING FORWARD; WINGS SLIGHTLY ARCHED

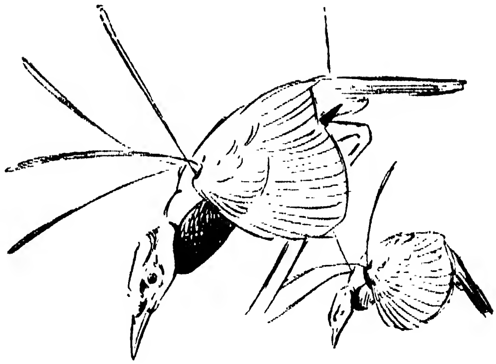

FIG. 3. BEGINNING OF USUAL DISPLAY; WINGS VIBRATING; CARPEL PLUMES ERECTED.

starting to drum, the bird suddenly holds the wings arched horizontally, and the entire body then quivers or vibrates for a fraction of a second. (Fig. 4.) The wings are held so that they may actually touch (or nearly so) at the wrists. The elongated white carpal plumes are erected with the first rapid wing beats and remain so now, and the inner ones of each wing actually cross in the air above the body of the bird. Occasionally both the inner and the outer pairs cross each other, but more frequently only the inner ones do so. The green gorget is sometimes only slightly raised, but in full displays it is completely elevated away from the body

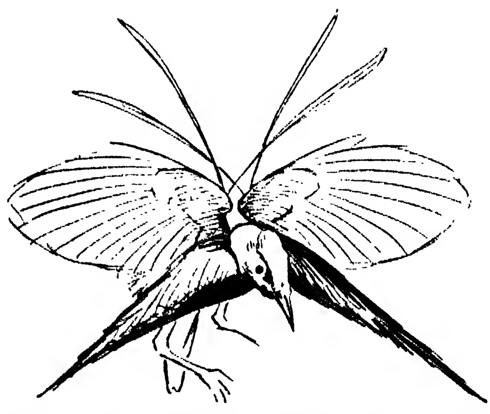

FIG. 4. FULL DISPLAY POSITION; WINGS HELD STILL.

except, of course, medially, and the two lateral attenuated apices are brought forward out on the sides. The short velvet-like feathers of the crown are ruffled and, when reflecting light, give an optical effect of a rolling beam of light traveling from the forehead to the occiput. While this pose is held the bill is kept closed, but the bird utters a series of low, guttural, almost whisper-like sounds like that of faint cracking of twigs. The throat dilates slightly as the successive notes are given.

The display may end here with the folding of the wings back to their usual position and the resumption of a normal upright posture, but two types of elaboration are often indulged in. Probably the displays that terminate here are incomplete.

In the first type the wings are suddenly stretched out fully horizontally, bringing the carpal joint (the point of attachment of the white plumes) far out laterally, and are held stiffly in that position for a second or two. The white plumes are still erected individually. (Fig. 5.) From a front view of the bird it looks almost as though the white plumes on either side were attached to the apical areas of the green gorget, which is held widely stretched at right angles to the body. The head may be raised somewhat during this stage, but the bill always points downward. The wings are soon folded, the plumes slowly

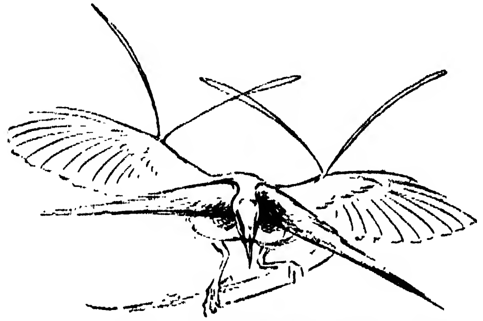

FIG. 5. WINGS STRETCHED LATERALLY AND HELD MOTIONLESS.

fall, the gorget relaxes and subsides, and the display is over. In some cases the wings are not stretched laterally, but merely stiffened. (Fig. 6.)

In the second type, the bird keeps the wings half arched and then leans backwards on its perch, presenting to the female a view of the gorget and the whitish plumes hovering behind it. It may let go of the perch and tumble over in the air in a backward somersault, landing on its feet with closing wings. This ends this type of display. The former type was much the more frequently indulged in in my experience.

Aside from the green gorget and the erectile carpal plumes, the antics of the bird in the first part of its display—bending over and arching the wings—is slightly reminiscent of the display of some of the Icteridae, but presents the following points of difference. The tail is never spread and is usually depressed, not elevated, in *Semioptera;* it is always raised and usually spread to some extent in the Icteridae. In *Semioptera* the bird bends over before arching the wings; in the Icteridae the wings are arched first. The guttural twig-cracking sounds are peculiarly like those made by some of the oropendolas (*Gymnostinops montezuma* and *Ostinops decumanus*).

It occurred to me that possibly in a wild state the displaying male would assume a position in the tree above the female to which he was displaying, and that this might account for the downward posture assumed before the real inception of display. I tried, therefore, putting the skin or skins, that I used to help excite the bird, on top of the cage, above his perch, etc., as well as below it, but the head-lowered position was not affected in any way by these changes. If the origin of this pose was as suggested, then it has become so stereotyped in its performance that it is no longer easily altered. Occasionally the

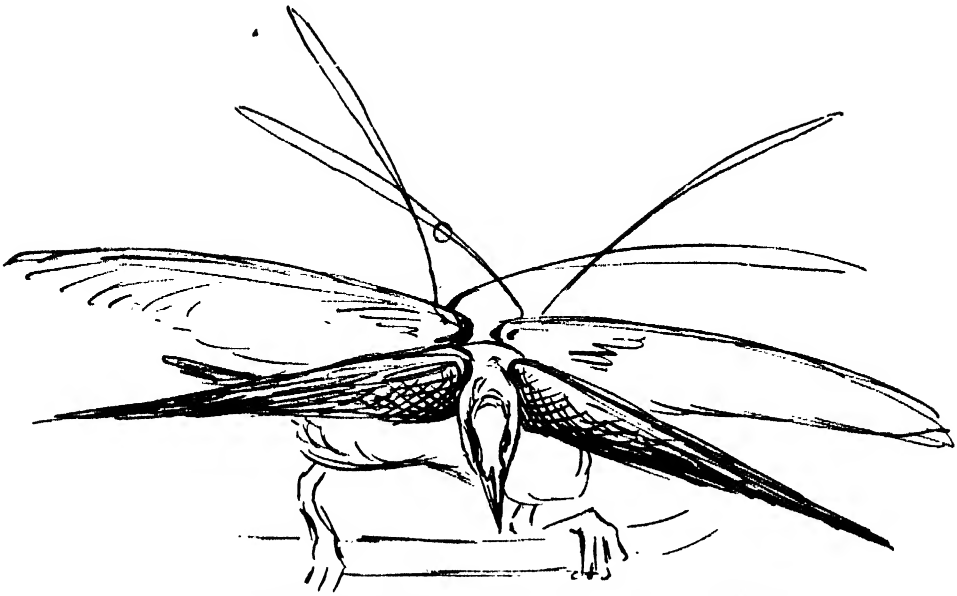

FIG. 6. POSITION 4 EXAGGERATED BY SUDDEN MUSCULAR TENSION

bird may bend downward so far that it is upside down when displaying.

On one occasion, at the height of the wing-arching stage, when the wings were almost touching at the carpal joint, the bird uttered a rolling almost trilling series of notes quite different from the rasping *tscharrr* or *arrrrh* notes given before the actual display. These individual notes were of the *arrrh* type, but clearer, shorter and less nasal in quality. Usually, however, the bird is silent while displaying, save for the faint twig-cracking sounds.

In all types of display, the white carpal plumes remain erect for a little while after the wings have been folded. It looks as though the tension required to raise them needs time to die down; that the bird can elevate them quickly but can not force them down as instantaneously.

SCIENCE SERVICE RADIO TALKS

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HOW WE REMEMBER

By Dr. SAMUEL W. FERNBERGER

PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF PENNSYLVANIA

I SUSPECT that there is not one of my listeners who has not recently mislaid something and who can not for the life of him remember where he put it. Or perhaps you have forgotten a name which you wanted to remember, or you have forgotten some important fact. It is a popular belief that forgetting of this sort is more true of old age. How often does one hear it said: "I must be getting old because I can't remember so and so." As a matter of fact such forgetting is perfectly characteristic of all ages. I hope before I am through to indicate how it is possible to improve your ability to remember.

Indeed the experimental results from the studies of learning and forgetting indicate that the situation is rather worse than most people suspect. The first experimental study of forgetting and remembering was performed less than 50 years ago, but since that time, there is probably no problem in experimental psychology which has been investigated in so many phases and on which so much time has been spent.

The results of the first study of forgetting, which was reported in 1885 by Hermann Ebbinghaus, indicate as well as any other how serious is this matter of forgetting. Before I indicate the results, let me briefly outline the experimental method. Ebbinghaus learned lists of nonsense syllables like some of those which have recently appeared in advertising. These lists of nonsense syllables were learned only to the point at which they could be first correctly repeated. Then periods of time were allowed to elapse ranging from 20 minutes to 30 days in order to determine the degree of forgetting for the different periods of time. When the testing of the amount forgotten was to be determined, there was no attempt to recall the series. Instead the series of syllables was relearned and the amount of time and the number of repetitions saved in relearning gave an index of the amount remembered.

Under the conditions, then, of learning lists of nonsense syllables to the point of first errorless repetition and testing the amount forgotten by the method of relearning, it was found that, after 20 minutes, more than 40 per cent. was forgotten; after 1 hour, more than 55 per cent. was forgotten, and after 6 days only about 25 per cent. was remembered. That is indeed a discouraging picture. Think of the teacher, for example, who may expect that more than half of a lecture will be forgotten one hour later and more than three quarters of what is taught on Monday will be gone by the following Monday.

Undoubtedly all of you have already thought of a number of criticisms, but I can assure you that most if not all of these criticisms are not true. These experiments have been repeated many times and the subjects in the original experiment did not have poor memories. But, of course, you will say, what can you expect when you learn such silly things as nonsense syllables. Let me assure you that many other sorts of materials have been used, such as lists of words, stanzas of poetry and selections

of prose, and invariably one has obtained similar results. It does not make any difference what materials one uses, forgetting takes place just as rapidly. And some of you may say, "But the material was tested by relearning rather than recall." And, on this point, I can assure you that the relearning which was employed will give a much better score than a simple attempt to recall. If these learned materials had been tested by recall, the results would have shown an even more rapid rate of forgetting.

But you will say, "I do remember things better than these results would indicate." Of course, this is true and the answer is to be found in one condition of the experiment. The important thing is that these materials were learned only to the point of first errorless repetition. In other words, they were just learned and no more. And you will find that if you just learn material, it will be forgotten quite as rapidly as the Ebbinghaus results would indicate. Many other experimental results on learning and forgetting indicate, however, that overlearning is necessary for more permanent retention. And these experiments show that a relatively small amount of overlearning brings enormous dividends in slowing the rate of forgetting.

One reason, therefore, why there is so much forgotten is because you have not sufficiently overlearned what you want to remember. How frequently does the school child say, when he has once succeeded in spelling a word correctly, "Well, I have that," and then turns to something else. And if the school child stops at this point, one may expect that 40 per cent. will be forgotten by the end of 20 minutes and 75 per cent. forgotten at the end of a week. And how often does the adult say, "I can't remember the name of the person whom I met last evening," when probably he has heard the name only once, and all too frequently, the name was not even clearly pronounced during the introduction. And how can you expect to remember where you have put your glasses when you did not even notice that you were putting them down? In other words, how can you expect to remember when there has never been learning at all, or when there has been insufficient learning?

Let me illustrate this principle of better retention as the result of overlearning with a very practical example. Many years ago I knew a gentleman who was noted for his ability to remember names—a characteristic which was of great value in his life as a politician. He quite frankly told me how he did it. It turned out that he did not have an exceptionally good memory at all. But he frankly and quite consciously set out to overlearn the name of any one whom he might meet. When introduced to Mr. Smith, he did not merely say, "I am glad to meet you," but he would say, "I am glad to meet you, Mr. Smith." And then he would say, "And now, Mr. Smith, what did you come to see me about?" "No, I do not believe that I can help you there, Mr. Smith." And so on, so that, within a few minutes' conversation he had repeated the name ten or a dozen times. It was this repetition —this overlearning—which enabled him to remember the name, not the fact that he possessed an exceptional memory.

Our time is too limited to discuss all the other many aids to remembering. But besides the principle of repetition and overlearning which I have emphasized, unquestionably the other most important factor is the formation of associations. By this I mean that any idea to be readily recalled must be associated with other ideas. It is the idea which stands alone and which has never been associated with other ideas that is at once forgotten. And conversely the idea which is hooked up with a great

many other ideas; that idea, in other words, that has entered into a rich constellation of associations with many other ideas—has far the best chance of being recalled when you want it. Let me illustrate with a practical example.

How many of my listeners can tell me who was elected Vice-President during the Harding administration? I suspect that not many of you can answer offhand and I also believe that not many could tell me at all no matter how much time I gave you to think about it. And what when I remind you that the Harding Vice-President was the late Calvin Coolidge and that Mr. Coolidge became President when Mr. Harding died while in office. Of course, now that I have reminded you, you will recall many things about this—how Mr. Coolidge's father swore him into office and all the rest of those dramatic incidents. There is no question of your remembering Mr. Coolidge as President, but you had forgotten him as Vice-President. This difference has its basis in the very fact that you had few associations with him as Vice-President and many associations connecting Mr. Coolidge with the Presidency. This is the psychological basis of all the variations of the joke about Vice-Presidents.

I can illustrate this principle of the importance of associations for permanent memory by describing a demonstration which I give to my classes each year to emphasize this fact. The class prepares a list of 30 common nouns. My assistant comes blindfolded into the room and the list is read to him just once—allowing him several seconds for each word. Immediately afterwards he will repeat the list forwards or backwards, give the position of any word in the list or the word for any position. For several years my assistant has done this without error, and it happens that this assistant has normally such a poor memory that he always carries a pad of paper with him on which he writes everything that he wants to remember during the day. The trick is accomplished by means of the assistant having a memorized list of thirty key words which he uses time after time. This list is so overlearned that he knows each word and its position in the list very thoroughly. Let us say that his third key word is "car" and that the third word in the list which the class has prepared is "elephant." My assistant will promptly associate his key word with the class word, usually in some bizarre fashion if possible. For example, he will see an elephant inside a trolley car. Later some one asks for the third word. My assistant knows that his third key word is "car" (because he has overlearned the key list) and he sees, in his mind's eye, the elephant in the car. With this associated cue he is then able to say "elephant." I have said that my assistant recalls the 30 words by the trick of forming associations between the words in his key list and the words of the class list. I then ask the class to reproduce the list, obviously without these associations—and I have never yet found a student who could do it, although the class has been making up the list and looking at it for probably a half hour. And there is nothing remarkable in this trick of my assistant. I can assure you that any one of you could do this trick within 24 hours if you were merely willing to take the time to prepare a key list and then take the time to overlearn it very thoroughly.

Let me give just one more example of the importance of associations for remembering. It happens that I am addicted to the reading of detective stories. In a recent story, it was important that one of the characters as well as the reader must remember a certain house number but not particularly important that the name of the street be recalled.

The character in the book receives a phone call sending him to this house, the number of which is "52." He is told over the phone, "Go to number 52 and remember that there are 52 cards in a deck and 52 weeks in a year." This is good psychology. The character and I both remembered the number, but I am sure that I have forgotten the name of the street.

I have talked of only two factors which are of importance for permanent remembering. There are many other factors but they are certainly of less importance. I can assure you that these factors of the formation of associations and of repetition until a material is not only learned but overlearned can not be overemphasized if you want permanent retention. And I can assure you that these principles are equally applicable to any age. Be you young or be you old, if you want to remember something, repeat it over and over again, adding as many different associated ideas as you can even after you are sure that you know it. In this way you will probably not improve your memory, but you will certainly be able to retain and to recall things ever so much better, which, after all, is what is important in the practical situation.

IS OUR CLIMATE CHANGING TO MILDER?

By J. B. KINCER

CHIEF, DIVISION OF CLIMATE AND CROP WEATHER, U. S. WEATHER BUREAU

In the latitude of the United States, we have certain very definite and regular temperature changes. One of these is the diurnal or daily march, with the minimum occurring on the average about sun up and the maximum at 2 or 3 o'clock in the afternoon. The difference between the lowest and the highest of the day is normally about 20 degrees. There is still another periodic or regular variation in the temperature with which we are all familiar—the annual march. The coldest month of the year is, on the average, January, and the warmest, July at most places. Variations in the annual range, that is, the difference between the average temperature for the coldest and the warmest month of the year, are greatest in the northern states and least in the southern. In North Dakota January, on the average, is about 62 degrees colder than July, while for Florida the difference is only 22 degrees. The range is least along the Pacific coast; in San Francisco January is less than 9 degrees colder than July. These periodic changes in temperature are due, of course, to the relative positions of sun and earth—that is, they are astronomical in character.

Other temperature changes, not so obviously of solar influence, are familiar also. We have short-period fluctuations in which different kinds of weather come and go in comparatively brief, alternating spurts, as it were, or with short periods of irregular length—sunshine, then rain; cool or cold, then warm—succeeding one another with a regularity that every one takes for granted. However, an exhaustive statistical examination of these short-period changes fails to disclose any regularity that affords a basis for forecasting future weather independently of the standard forecasting methods of the Weather Bureau, in which daily synoptic charts play an important rôle.

In addition to these short-period fluctuations, we have long-time trends in temperature. Perhaps most of you

either have expressed the opinion personally or heard it expressed by others, that our climate is changing—that it is becoming warmer, despite an occasionally severe cold wave in winter or an untimely and unwelcome frost in spring or fall. With "Grand-dad" insisting that the winters were colder and the snows deeper when he was a lad and most of the rest of us realizing that in recent winters we have not been getting our full quota of cold weather, as measured by bygone standards, it was decided to make a rather exhaustive study of the question. We believe you will be interested in some of the results this study has disclosed from the records up to and including the year 1933.

We might give a few illustrations of recent abnormal warmth. An examination of the temperature records for Washington, D. C., shows that for the last 21 winters 18 have been warmer than normal; that every one of the last 13 was mild, and that the warmest winter of record, going back considerably more than a century, was that of 1931–32. In passing we might mention that this is in marked contrast with "Grand-dad's day," say from 1854 to 1873, when 75 per cent. of the winters were colder than normal; the winter of 1855–56 was the coldest in more than 100 years. The record for New Haven, Conn., shows that every one of the last 10 winters has been relatively warm; also, 18 of the last 21, and 33 of the last 45. This New Haven record, by the way, goes back to near the close of the Revolutionary war. Further west, we pick up, at random, the Saint Louis record, which shows 13 of the last 15 winters with above normal temperature. By normal, we mean the long-time average.

When we examine the records for other seasons of the year, such as the spring and fall, similar conditions are disclosed. For the spring (March to May, inclusive) we find in the case of New Haven that 20 of the last 24 springs were relatively warm, which contrasts sharply with the 10 successive springs from 1866 to 1875, every one of which had a mean temperature below normal; the Washington, D. C., record shows only 8 springs with below normal warmth during the last quarter of a century. In Saint Paul, Minn., more than 75 per cent. of the fall seasons for the last 43 years have been warm, in contrast to the 37 falls from 1840 to 1876, inclusive, during which only 9 were warmer than normal. Here in Washington, only 4 of the 25 falls since 1907 have been below normal temperature. The Weather Bureau maintains about 5,000 weather stations scattered throughout the country and the records for these we have mentioned are typical of others over the central and northern portions of the United States east of the Rocky Mountains.

In view of these facts, is it any wonder that people are asking the question "Is our climate changing?" It might be stated, however, that the abnormally warm weather experienced in general for a long time past does not mean that cold periods have been entirely absent. On the contrary, the records indicate that occasional brief spells of abnormally cool or even extremely cold weather are characteristic of prevailingly high temperature trends. The lowest official temperature of record for the United States—66 degrees below zero—occurred last winter in the Yellowstone National Park, notwithstanding the winter was decidedly mild over much of the greater part of the United States. Again the past winter, or that of 1933–34, and especially the month of February, has been abnormally cold in our northeastern states, with the establishment of new low temperature records at many places. However, the area affected is relatively small, as much the

greater part of the country has had decidedly mild weather, with a large northwestern area enjoying one of the warmest winters ever known. In meteorological work the winter is considered to include the calendar months from December to February, inclusive. In other words, we have been having brief cold spells and an occasional cold winter, but at the same time mild weather and warm winters have greatly predominated for many years.

We have just contrasted the frequency of recent warm winters and springs and falls with conditions shown by the records to have obtained some 50 to 75 years ago when there was a marked tendency to colder weather. Now these long-time temperature changes are quite similar in many ways to the seasonal changes we experience every year. For our geographic location, when we compute the day by day, or week by week, average of temperature for a long period of years, we obtain what is known as the normal for that day or week. In the normal annual march of temperature the lowest of the year falls about the middle of January, called mid-winter, and the highest about the middle of July, known as mid-summer.

When the turning point is reached in mid-winter there is a very definite and regular increase in the normal temperature curve, slow at first, but becoming more pronounced in March and April, after which the rate of increase is retarded until the highest point is reached in July. However, it is only the normal or average that has this regular trend. For any single year the rise from mid-winter to mid-summer is frequently interrupted by short-period fluctuations, each a few days in length—warm, then cool, in succession. This and the fact that the rise is very gradual obscures the seasonal march, and there is a lapse of some time before we are conscious of a permanent change to warmer weather. It is finally realized, however, as the season progresses, that the cold spells are becoming less frequent and less severe and the mild ones warmer.

So much for the annual march of temperature that carries us from the cold of winter to the warmth of summer, a change requiring only a few months to accomplish. In studying the long-time temperature trends we may, for a clearer understanding of their general nature, consider that the centuries, too, have their winters and summers, just as do the years. These trends, from periods of relatively cold to comparatively warm weather, are very similar in nature to the seasonal march in temperature from winter to summer, though here the shorter-period fluctuations that interrupt the general trends are measured in years instead of by days as in the other case. When these are smoothed out, as we smooth the day-by-day fluctuations to obtain the normal annual march, we find very definite long-time trends in the same general direction for many years—that is, tending either to cooler weather or to warmer as the case may be.

Our longest temperature records in this country are for the central and eastern states and go back something more than a century. These show that some hundred years ago the general trend was receding, apparently from some undetermined higher point still further back for which records are not available, and that this recession continued, with comparatively minor interruptions, to about 1865. From this date the trend curves show a more or less steady rise up to the present time. For the last 25 years this rise has been especially rapid which has carried the curve much higher than at the point where the door was opened upon the scene by the beginning of records many generations ago. In other words the abnormal

warmth during the past 20 or 25 years has no precedent in records available for study, notwithstanding the longest go back to Revolutionary war days. The change in the trend lines from the lowest, more than half a century ago, to the present time is rather impressive. For example, the 20-year average temperature for the winter, spring and fall seasons up to 1933 are from 2½ degrees to nearly 4 degrees higher than similar averages up to 60 or 70 years ago. This is quite a difference when we are considering averages for a 20-year period comprising seasons covering 3 months each.

The records for the different seasons of the year show that the winter trends are the most irregular, with the up-and-down secondary swings of greater frequency and shorter in duration than those for the other seasons. For the spring and fall the trends have been more uniformly upward, with fewer interruptions by short cold spells.

Doubtless some of you are now ready to inquire, what about other parts of the world? Are these conditions peculiar only to the areas covered by the records discussed, or is the summer of the centuries prevailing in other countries, also? To determine this, we have examined a number of long temperature records for different parts of the world, using the same smoothing device as before. These represented Canada, France, Spain, Italy, Austria, Poland, England, the Scandinavian countries, Mexico, South America, Africa and New Zealand. They are all in substantial agreement in showing upward temperature trends for a long time past, except that some low latitude areas, especially the Mediterranean countries, were negative by indicating moderate recent trends to cooler.

We have said that something more than a hundred years ago we were coming out of a warm period apparently something like that in which we are now in the midst. If we had records covering a few hundred years still further back, doubtless some interesting facts would be disclosed. As it is, they are not long enough to cover a complete cycle, that is, from one major warm peak to its successor, and consequently, they do not afford even an inkling as to just how much longer the present warmth may continue or how much higher the trend curve may go, if any.

THE HUMAN-ANIMAL DISEASES

By Dr. DAVID J. DAVIS

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The earliest reference to disease in any literature concerns pestilence or epidemics involving both animals and man. This was because man in primitive times lived in intimate association with the various domesticated animals upon which he was largely dependent for food, clothing, transportation and protection. Diseases common to men and the lower animals could in this way be easily transmitted.

One of the first references to a definite pestilence appears in Hebrew literature in Exodus 9: 3, where it is stated, "Behold the hand of the Lord is upon thy cattle which is in the field, upon the horses, upon the asses, upon the camels, upon the oxen and upon the sheep: there shall be a very grievous murrain." This curse was sent upon the Egyptians because they refused to heed the words of Moses. In the writings of the Greek

mythology, reference is often made to Apollo, the god of healing and father of Esculapius, who was able with his far-darting arrows to scatter plagues among both humans and animals and as easily to withdraw such influences.

The first great pestilence of which we have a definite record was the Plague of Athens in 430 B.C. Thucydides gives a vivid description of this terrible epidemic, which killed on such a vast scale that, as he states, cities were almost depopulated and great piles of human bodies remained in the streets unburied. He makes this interesting comment: "For the character of the disorder surpassed description; and while in other respects also it attacked every one in a degree more grievous than human nature could endure, in the following way, especially, it proved itself to be something different from any of the diseases familiar to man. All the birds and beasts that prey on human bodies either did not come near them, though there were many lying unburied, or died after they had tasted them. As a proof of this there was a marked disappearance of birds of this kind, and they were not seen either engaged in this way, or in any other; while the dogs, from their domestic habits, more clearly afforded opportunity of marking the result I mentioned." What this disease was has never been determined, though the subject of dispute for years. Some critics have thought it to be a form of glandular plague, even though Thucydides did not mention buboes. Others believe it to be some other highly contagious disease, possibly typhus fever. However, if birds and dogs were susceptible, it would indicate that it was some disease other than plague or typhus, for neither animal is susceptible to these diseases under such conditions. Probably anthrax would explain the facts better than any other disease known to-day. This is the first known observation on the transmission of a disease through the eating of contaminated flesh from the human to an animal. To-day, in human-animal diseases, the infection nearly always passes from the animal to man.

The second great pestilence in recorded history was "The Plague of 166 A.D.," often referred to as the "Plague of Marcus Aurelius"; also the "Plague of Galen." Both Galen and Marcus Aurelius lived at that time in Rome. Marcus Aurelius has left no record of this plague. He himself died of it in 180 A.D. Galen described it and from his writings most authorities conclude it was the same disease as the plague of Athens in 430 B.C., whatever that may have been. White, in his recent volume on Roman history, refers to this catastrophe as perhaps the chief cause of the decline and fall of Rome. He states that the empire never recovered after the enormous mortality, the disorder and confusion and the depressed mental state and loss of morale that followed this plague. Gibbon mentions it, but stresses it less than other writers.

The Justinian plague, beginning about 530 A.D. and continuing for some 50 years, was another one of the greatest catastrophies of all time. Man and animals were involved. From the descriptions available the evidence seems convincing that it was real bubonic plague, though from some of the records it would seem that more than one disease prevailed. It is possible that bubonic plague, typhus, smallpox and anthrax all may have raged at the same time. The simultaneous occurrence of several infections is a possibility that may explain many of our difficulties in identifying the true nature of these ancient afflictions.

Nearly all writers assume that these pestilences were diseases that are in existence at the present time, and hence in their studies they have attempted to identify the disease with one of our mod-

ern plagues. After a thorough study of the evidence, we are forced to the conclusion that some of these great plagues may have disappeared completely. There are two such diseases known to have occurred in relatively modern times; namely, the sweating sickness, beginning in England in the sixteenth century, and trench fever, which appeared during the recent world war. We have fairly accurate descriptions of both. So far as we know, neither exists anywhere to-day.

Comparative medicine may justly lay claim in a very definite way to one of the great men of history, the Roman poet, Virgil. He has been pronounced the world's greatest veterinarian. Fortunately, perhaps, he was not a trained scientific veterinarian or medical man, for if he were it might hrve interfered with his poetry. No medical writer has approached him in describing disease. His most celebrated description concerns anthrax, at that time in Italy a prevalent disease afflicting man and many lower animals. Its havoc must have impressed him deeply. The sources of infection he seemed to know quite clearly and refers to them as follows: "From tainted air arose a dreadful storm, influenced by autumn's heat, and gave to death all cattle tame or wild, corrupting lakes, poisoning the grassy food." In his incomparable verse he describes various animals, revealing the different stages of the disease. He notes the young cattle, the "fawning dogs" and the sick swine. To the horse, his favorite animal, he devotes some of his finest art. He tells how the bull and the oxen in the fields are stricken. Then the wolf, the deer and the flying stags and "in the sea all swimming things like shipwrecked bodies float washed by the waves." Even the viper dies and the birds infected by the wind fall and "leave their lives in the lofty air."

Finally coming to man, he gives the first description on record of wool sorters' disease or pulmonary anthrax. He evidently was aware of the persistence of the disease in the soil, due, as we know now, to the anthrax spores. For he says, referring to the dead animals (quoted from Fleming),

Tell men dig deep and bury them in earth
The skins are useless, nor the tainted flesh
Can water cleanse nor raging fire subdue;
Nor is it possible to sheer the fleece,
So damaged with disease and filthiness;
Nor can the weaver touch the putrid web.
But should a man attempt the odious garb
With burning pimples and disgusting sweat
His limbs are seized, and in no lengthened time
The fire accursed consumes his poisoned frame.

No doubt we must grant to Virgil the poet's license in liberal measure. But making due allowance for this we observe there is much solid information, indicating that these human-animal diseases were widely prevalent and recognized as directly transmissible from animals to man.

Not only in these ancient times but continuing down through the dark and the middle ages, the literature is replete with references to the diseases common to man and animals. The idea was prevalent that some general cause was responsible, such as tainted air, storms, earthquakes, etc., all more or less determined by the gods. Here and there, however, we note the growth of a more definite scientific conception of a direct transmission from animal to animal or from animal to man.

In our present day we are still confronted by these same problems. Just now there seems to be an especial danger threatening man from several diseases of the lower animals which serve as reservoirs for the infecting agent. Undulant fever, psittacosis or parrot fever, tularemia or rabbit fever, fish tapeworm, septic sore throat, sporotrichosis and actinobacillosis are some of the more modern ones which we fear. Rabies, bovine tuberculosis, anthrax, glanders,

actinomycosis and bubonic plague are the more ancient diseases of this type. More and more attention is being directed to them. While some are very old, others are new or at least only recently recognized. Some seem to have been rare in the past, but at present are rapidly spreading. Practically all are carried from lower animals to man; almost never is the reverse true.

Our domestic animals play the most important rôle in transmitting these diseases. Fortunately, wild animals are less often involved. When infected, however, the latter, owing to the difficulties of control, present extremely serious problems.

Man is infected both directly and indirectly from animals. Direct and intimate contact is common and in some diseases like glanders and parrot fever is the usual route of infection. In other diseases ingested food products, including milk and meat, are the usual or almost exclusive mode of transmission. Bites are responsible for transmission, especially in insect-borne infections. For certain dangerous organisms the soil is the chief reservoir from which in different ways the germs infect animals and man. At times the routes of transmission are exceedingly devious and difficult or impossible to trace.

There are many human diseases whose transmission and control can be understood only through studies on lower animals. Such studies include experiments on normal animals and observations on sick animals. As examples, may be mentioned septic sore throat, rabies and undulant fever. Septic sore throat occurs in epidemic form, at times affecting hundreds of persons at once. It arises from drinking milk from cows whose udders are infected with a dangerous germ, the epidemic streptococcus, which enters through the teat from the milker. Mastitis or infection of the udder is a very common disease of cows, but fortunately most of these infections are not dangerous to man.

Undulant fever is common to several kinds of domestic animals and is transmitted to man either by contact or through the use of animal food products. Formerly we considered it rare, but now we know it to be wide-spread. It is one of the major health problems involving both humans and domestic animals. In its solution, as in the solution of most of these animal-human diseases, the cooperation of the veterinarian with the physician is necessary.

Rabies continues to be too common. Even the very rare case should always be considered a threatening menace to both human and animal species.

Tularemia is widely distributed in the animal world and is caused by a small bacillus. In this country human beings are infected chiefly from the rabbit. Hence we see it mostly in hunters, butchers and in women who prepare the carcasses of this animal for food. A primary lesion appears on the exposed part, commonly the hand, from which the infection spreads to the neighboring lymph glands. It is usually not a fatal disease. A campaign of education and proper warnings conveyed to persons exposed should do much to control it.

Swine erysipelas is an infection occasionally carried to man from hogs. The disease is rare in the United States, but in Europe it is common and a few human cases have appeared. Recently a serious outbreak of 80 cases appeared in a button factory in Virginia. Buttons were made there from the bones of infected hogs.

Actinobacillosis is a disease primarily of cattle and is similar to the well-known lumpy jaw or actinomycosis. Man is infected occasionally in the United States, more frequently in Europe for some reason. Both this disease and swine erysipelas, now rare in man, should be

carefully watched. They may be just emerging from their reservoirs in the lower animal world up into the human, where it is difficult to predict how dangerous they may be.

Parrot fever or psittacosis has several times recently gained the front page of the newspapers. It is one of the most contagious diseases known, being transmitted directly from parrots, parrakeets, love birds and several other varieties to man. It is caused by a filterable virus. Argentina has been its habitat for many years, but recently more or less of a pandemic has appeared and now it appears to be widely disseminated. California seems at present to be the chief focus in the United States because of the extensive aviary industry there.

Sporotrichosis is a fungous disease infecting man, the horse, mule, rat, dog and some other animals. While never as yet a common disease, it occurs in certain countries often enough to occasion some alarm. In France, Argentina, South Africa and the United States it has gained a foothold and isolated cases are observed from time to time. At present it does not seem to be on the increase. The fungus is apparently present in the soil or on plants in certain localities, from which sources man and animals become infected usually through slight wounds in the skin.

It is noteworthy that we now know enough to control most diseases of this group thanks to scientific studies carried on in the fields of both veterinary and human medicine for the past half century or more. As a rule the problem is to apply the facts we now know. The difficulties may be practical and due to failure to control the conditions. Other difficulties may be financial, where the cost of control is prohibitive, or an ignorant public may resent interference for one reason or another. Many of the problems are at bottom social ones and campaigns of education in both human and veterinary fields are indispensable. Nevertheless progress made in the last fifty years in both fields is nothing short of miraculous from the standpoint of disease control and relief of suffering.

SCIENCE AND INDUSTRY IN THE COMING CENTURY[1]

By ALFRED P. SLOAN, JR.
PRESIDENT OF THE GENERAL MOTORS CORPORATION

First, I wish to express my appreciation, and that of my associates, for the courtesy extended by every one of you in joining us at dinner here this evening. The endorsement and support of such an outstanding group of thought and action, of Chicago and elsewhere, as is here assembled, represents in itself no small honor and should in itself carry conviction as to the importance of the message to be presented.

To-night, here at the Century of Progress Exposition, we find ourselves surrounded at every turn with the marvels of the age, made possible by the progress of science, capitalized through the instrumentality of industry. In the progress here recorded is written the lives of countless numbers who, through sacrifice, courage, conviction and the opportunity and encouragement that has been accorded them, have brought these wonderful things into being. There results a higher standard of life, social and economic, and a broader opportunity for countless millions. What we see here at the moment is the cumulative development of the past century, more particularly of the past two decades. Out of that past comes the knowledge of experience and the inspiration of achievement. Certainly a sound foundation to build a still greater future—and it is to that future that we address ourselves this evening.

What is to be the progress of science and industry during the next decades? Is there any logical reason to assume that progress is to be halted at this particular point in our development? On the contrary, have we not every right to believe that the very progress of the past insures still more progress in the future and at an accelerated rate, if we have the breadth of view-point and the knowledge of the facts to properly manage our affairs?

There is involved the possibility of still higher standards of living. There is also involved a still broader opportunity for all.

Unquestionably, the most fundamental problem before us in this country and, in fact, before the world to-day is the question of unemployment. This is true whether that problem be one of cause or effect. Is the solution in the acceptance of the principle upon which so many of our national economic policies are to-day being formulated, that to have more, we must produce less? And now comes an amendment to that principle, that we should continue to produce the old thing—we must not produce new and better things. Again, can we even imagine that the solution of this vital problem lies in the arbitrary discrimination of one industry as against another, through controlling the freedom of the individual to exchange the results of his own labor, according to his own judgment and desires? Are we to believe that the amount of useful work to be performed is limited to what it is to-day

[1] Alfred P. Sloan, Jr., President of General Motors Corporation, arranged a dinner-symposium on "Previews of Industrial Progress in the Next Century" which was held in Chicago on May 25, the evening preceding the reopening of the Century of Progress Exposition. In response to a telegram Mr. Sloan received nearly three hundred expressions of opinion from leaders of science and industry. This article gives the opening address by Mr. Sloan and a number of the statements prepared by scientific men.

and that the problem of unemployment is solved by dividing the amount of work by the number of workers, or are we to believe that the amount of work can be expanded, given the proper economic machinery to make that possible? Can we look forward with confidence and conviction that if we turn back to the principles which have made this country what it is, and which we are to-day discarding; if we eliminate all artificial barriers that have been erected; if we encourage rather than discourage; if we reward rather than penalize constructive effort in the future, as we have in the past, that we can consolidate and accelerate the processes of natural recovery that we all believe are very definitely in the making throughout the world? What can science and industry contribute to such an objective? The purpose of our discussion this evening is to deal with this question. Manifestly, the subject is a broad one. A survey of many branches of useful endeavor discloses the fact that great thought and effort is being expended and real progress effected toward what we might call bigger and better things in the not distant future. These things affect all phases of our daily lives; they indicate still broader opportunities ahead; they demonstrate that the world is in no sense finished. What we must do is to establish and then to recognize what the possibilities are; what can be done—then to direct our efforts toward that objective. We will not be true to the traditions of our great and wonderful country if we become satisfied with a static position, either in our thinking or in our action.

Unfortunately, it is possible to present this evening, in the limited time at our disposal, only a few illustrations of how science is ready to show the way and industry to blaze the trail toward our objective. The picture will be presented by leaders of science and industry who, through actual contact with the problem, speak with authority of those who know. I sincerely regret that we can not hear from so many others present who could contribute with equal force and authority.

By Dr. CHARLES F. KETTERING

VICE-PRESIDENT IN CHARGE OF RESEARCH, GENERAL MOTORS CORPORATION

THE whole world is now absorbed in a study of social problems. These problems were brought about largely by the war. The depression has had a lot to do with clarifying science and industry's part in these problems. As to what we do in the future will depend altogether upon how good a perspective we have as to what we know and what we do not know. The ultimate aim of all industry, science, government and sociology is for a better life—better living conditions; better health; better food; better government; better houses; in fact, for better everything. And these can come about only in proportion as our daily routine and activities conform more nearly to nature's laws, which we understand so poorly at the present time.

The very fact that we have a lot of trouble is the best indication of this lack of understanding. Any group of scientists and engineers can sit down and write a long list of things which can be accomplished in the future. And it can also be written down that these things will come to pass when our government, social and economic situations develop to a point where they are desirable. And when these new products are presented, if the people accept them, they then become the beginning of new industries which will absorb a great many of our unemployed.

This list which we are discussing is merely the extension of what is in evidence to-day. And of itself it has sufficient vitality to produce new jobs and

new commercial activities to pick up our entire unemployment. But we must do something about it. Just talking will not produce the results.

It is my impression, however, that we are on the eve of things of an entirely different nature than the mere extension, refinement and development of our present-day scientific knowledge. I feel we have upon us in the immediate future a great change in mental attitudes toward the physical world which would bring into existence new pieces of information which will completely change our scientific view-point. It is not what we know that is so important. It is what we do not know. Most of what we know can be found in libraries, in the minds of people and in process as they exist to-day. But we have no conception of what a small percentage this is to what there is yet to know.

As an illustration, we perhaps do not recognize it, but everything that ever moved on the earth has been moved by energy which came directly from the sun. Our coal and oil deposits, our forests, our crops and everything that lives on the earth is simply an energy contribution from the sun. We do not know, except in a very superficial way, how the energy which is given out by the sun is transmitted to the earth. We do not know how plants pick up this energy and convert the inanimate carbon dioxide and water into the vital materials so necessary for our existence. This, when understood, will open up an entirely new conception of things that can be done.

It is not difficult with this information in hand for even the most unimaginative person to predict the propulsion of airplanes by radiated energy with the power plants located on the ground. Nor is it difficult to envision the entire system of aerial transportation which would be unaffected by fog and weather conditions in general. Most of this work is being studied to-day under the name of photo-synthesis—that is, how plants grow. And we have one research which, for want of a better name, we say is trying to find out why the grass is green. We must understand something of these processes of radiated energy before many of the great problems which lie ahead of us can be solved.

So much of our information to-day does not consist of basic understanding. It is known to us only by definitions. We say we can see through a pane of glass because it is transparent, and yet we do not know the first principle of how light is transmitted through glass. We say a copper wire is a conductor of electricity, and yet even our best scientists do not know, even in a small way, how electricity passes through one. We rub our hands together; we say they are warmed by the friction, and yet we have no knowledge to-day of the magnetism of friction. We know we have ball bearings, but as to the exact action of lubrication little, if anything is known, and in the commonplace things that are used in the electrical industry, such as magnetism, electric charges, etc., we have only a very superficial knowledge. We know these things exist, however, because we can see the effects of them.

Each year we discover new things, which a short time ago we did not even know existed. This has been true in the case of food and vitamins and other principles of nutrition. I can not help but feel that in a very short time we are going to break loose another great piece of basic information which will keep us industrially busy for a great many years to come. I think if we write down as our immediate problem those things with which we are dissatisfied we have a long list of things to do. We can make our cities less noisy; we can take dirt out of the air; we are air-conditioning our houses; we can have television and an unapproached number of other things. Now if we will go ahead and do these things which are evident, to the

best of our ability, and still keep an abiding faith in what we know and in what we do not know as having possibilities of great contributions to human welfare, there will be no need to fear the future.

There are many people who doubt if human progress can continue on its present standards. Still others think that we have to go back to lower standards of living because they see no way out of our present difficulty. There are, however, a substantial number who, knowing something of the development of civilization, do not regard the evidence presented as justifying either a static or a retrograding standard of living. Our assemblage around this table, made up of all classes of scientists and industrialists, consists of all the talents from that group of our American people who do not believe the world is finished or that we must curtail human effort and desire. But on the other hand we do believe that the only way out of our present difficulty is forward and not backward. To those of us who have spent most of our time in experimental and developmental work failure is a common thing and if we gave up the principle every time an experiment failed we would accomplish nothing. If common sense dictates that our objectives are sound, we must keep on failing and learning and failing until the objective is obtained.

Our civilization as a whole is new. This is the first time in the history of the world that such a civilization has been in existence. It in itself is an experiment, and just because we have encountered difficulty is no cause for despair. We must find out what is wrong and then remedy it, but we must not give up hope of a better and more secure life.

Almost every group of human society has been blamed for our difficulty, and the group which we represent has come in for a good measure of criticism. Most of this has come from people who do not know, either through the lack of imagination or experience, how to project the future. We welcome criticism and are open to suggestions as to how to do our work better. We feel that this depression is just one of the echoes of the great war. Nevertheless it is a reality and everybody must do what he can to help in every way possible to tide over these difficult times.

We are being told that if we develop new things we must accept the responsibility to see that they are properly used. We can not accept this proposition. First of all, we do not know when we are developing a new tool of human usefulness, and secondly a mind turned in fact-finding and experimentation does not make either a good politician or a social worker. We believe that many of the principles that have been developed in the physical sciences can be used in the study of the social sciences and we stand ready to contribute in any way that we can to this work. In the conception of any new project few people can see its significance, but when difficulties are encountered they always want to turn back. Christopher Columbus had exactly this experience with his crew, and while he did not reach his objective the result of his bold voyage resulted in a very much more important thing than that which he started out to do.

This same thing holds good in practically every human undertaking. We must believe both in the integrity of the people and in the motive which drives them on to their new undertaking. We must also have an open-mindedness in dealing with all new problems. When Faraday was experimenting on some of his first work in electricity a member of Parliament said, "What use can this ever be?" He replied, "You may be able to tax electrical apparatus some day."

This has, we all know, come true. In the short space of time between the Century of Progress of 1933 and to-night, a

great many significant steps have been made in all branches of science, industry and human relationships. These will be discussed by our distinguished guests. While no one can predict what the significance may be, we know that these new things have as great a potential at this time as any other great discoveries had in times past, at their inception. Every activity has before itself many great jobs to do. Perhaps one of them that concerns us most is with health. The doctor has done a wonderful job in his long tedious journey from the medicine man of ancient time, with his attempt to scare away evil spirits, to the present day of scientific approach and intelligent diagnosis. It will take him many years of the new century to understand all the delicate chemical reactions that go on in the human system. The physicist, the biologist and the engineer are all being asked to lend their assistance in this great work. The exhibit of medicine, surgery and general health education is one of the most important in this great exposition, in which we have a part.

Most people think that science and industry are interested only in the development of labor-saving machinery. This is entirely a false notion. But we must not forget that for the past 50 years when the great building of our railways, cities and industrial plants was going on this labor saving was a most important thing because we did not have enough people to do the work. And only five years ago we had a scarcity of labor in this country. We are all very much more interested in the production of labor-producing projects and invention than we are in labor saving, and it is our desire to present to you to-night this point of view. If you will only recognize how much there is yet to be done that will be of general good to the whole human family, then we need not worry, but we must be bold enough to take those forward steps which will bring back prosperity in any measure that we desire or in any measure which we have imagination enough to conceive.

By Dr. F. B. JEWETT

VICE-PRESIDENT OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY AND PRESIDENT OF THE BELL TELEPHONE LABORATORIES

In the field of electrical communication, with which I am most familiar, the history of the recent past and present condition of our technical understanding and the prospect of enlarged benefits in the future are such as to leave no scintilla of doubt in my mind that continued activity in research and development will be as productive of benefits in the years ahead as it has been in those of the recent past. While no one in this field of applied science, any more than in any other, can say specifically and with certainty just what can be accomplished in the next five, ten or twenty years, we do have very definite assurance of the possibilities of substantial accomplishment and of the general directions in which these accomplishments are to be looked for.

Substantially all present-day electrical communication, which has given the world its far-flung and extensive network of telephone and telegraph communication facilities by wire and radio, with its direct and indirect employment of hundreds of thousands of men and women, has been accomplished in the period since the time of the Centennial Exposition in 1876. All of it has been the direct result of painstaking research in fundamental and applied science. While the groundwork of our present structure is laid in the fundamental science discoveries of the nineteenth century, practical application of these dis-

coveries in 1876 was confined to essentially primitive forms of land and submarine cable telegraphy. Had scientific research and development in this field ceased or been materially retarded with the holding of the Centennial Exposition, electrical communication would have continued to be essentially a weak and insignificant tool in our social structure. It would have afforded little direct employment and would have been but little effective in building up and bettering our social structure.

In 1876 there was no art of telephony whatever. There was likewise no art of wireless transmission either for point-to-point, person-to-person or broadcast transmission of intelligence. There was no way possible of communicating intelligence to mobile objects, such as ships, beyond that afforded by the slow methods of visual signaling within the limited area of the visual range. There was no art of recording and reproducing sound, such as is involved in our modern phonographs and talking motion pictures, both of which are the direct by-product results of research and development work in the field of electrical communication.

In the period which has elapsed since the time of the Centennial Exposition, and particularly during the last twenty-five years, progress in the field of electrical communication and in related fields, as a direct result of scientific research and development, has been enormous. New arts of inestimable value to society have come into being, have given rise to remunerative employment to hundreds of thousands of men and women, and have added materially to the betterment of living conditions. The direct results definitely allocable to these advances through science, while enormous in themselves, are insignificant as compared with the indirect results which have followed in the train of a quick, reliable and world-wide introduction of electrical communication in all its varied aspects. If we were overnight to eliminate the results of research and development work in the field of electrical communication during the past twenty-five or even the past ten or fifteen years, the dislocation of the social and industrial structure would be appalling. Many of our everyday activities would be enormously curtailed, many of them could not be carried on at all, and vast numbers of the population now gainfully employed would be added to the army of the temporarily unemployed.

The processes by which our present-day results have been achieved through continued scientific research and development have been accompanied by a steady progress in the methods and tools by which this type of progress can best be accomplished. We have to-day, in the numerous great industrial research laboratories concerned with the problems of electrical communication, powerful weapons for attacking the problems of the future and for making full and immediate use of every discovery in the field of fundamental science which is applicable to a betterment of electrical communication. We have a vast store of accumulated knowledge and a greatly increasing amount of information as to where further effort can be applied to a betterment of electrical communication.

We know that despite all that has already been done, there are still great opportunities for the improvement, extension and cheapening of our present systems of telegraphy and telephony. We know that unless our present efforts are artificially restrained through short-sighted conclusions predicated on a narrow viewing of the current effects of the depression, we can very greatly extend and cheapen the facilities of electrical communication to the very great benefit of the entire social and economic structure. There is no sound basis for believing that achievement of these prospective objectives, through continued scien-

tific research and development and practical application of the results, will have any different effect on employment and standards of living in the future from that which has been the invariable result in the past.

In the past, in the field of electrical communication, every substantial step forward through scientific research and development has carried with it increased employment and has been in the direction of a better standard of living. Whole arts have been created to afford employment to vast numbers of people where no employment whatever obtained before. Each extension of service and each thing which has resulted in cheapening or bettering the service has likewise resulted in increased direct and indirect employment. It is inconceivable to me that continuation along the path which we have been following will carry in its train a complete reversal of these results or even a substantial modification in the effects on employment and living conditions.

By Dr. W. R. WHITNEY

VICE-PRESIDENT IN CHARGE OF RESEARCH, GENERAL ELECTRIC COMPANY

AMONG the future developments which immediately suggest themselves are:

Air conditioning-temperature and humidity control, in homes, offices, schools, hospitals and other public buildings; light, stream-lined, low center of gravity trains for speeds of 100 to 200 miles per hour; electrification of all railroads; trunk highway systems avoiding cities and towns and separating passenger cars from trucks; highway lighting, making high-speed night driving safe; flying at high altitude for increased velocity and economy, automatic piloting and landing control from ground; complete substitute for visual control, perhaps including micro-altimeters and micro-fathometers, for making flying and navigation safe in thick weather; home teletype by radio, giving up-to-the-minute news; home motion pictures by radio; home television for events of interest; reduction in cost of power as by mercury boiler, coal used at mine, etc.; high voltage, direct current transmission, reducing power costs and extending economic radius; new materials—improved textiles, new synthetic resins replacing wood, metals and other natural materials for many purposes; new alloys, new structural materials giving better heat and sound insulation; production of new and useful mutations and control of malignancies by x-rays; elimination of needless noise; elimination of slums, extension of parks, widening and beautifying city streets; household drudgery ended by complete electrification of every home; all routine industrial and clerical jobs made wholly automatic; increased productive efficiency, resulting in more goods for all, with greatly reduced working hours.

These items are mostly in the engineering stage already. That is, the scientific discoveries on which they are based are already at hand. Scientific work, or careful curiosity, has always disclosed unexpected facts on which new engineering is based. Almost every one of our great engineering assets was at first a mere useless scientific curiosity. This is true of gas engines and of aluminum, for example. It is true of electricity and most of its applications. For years electric welding (which now accounts for miles of pipe lines) was largely a curiosity. Radio, itself, was unforeseen and is the result of scientific curiosity, while radio tubes, for generation and for reception, were not anticipated, but discussed as novelties of science.

Moreover, we ought to expect science to start even more wide-spread engineering developments in the future than in

the past, because there are widely spreading fields and more distant areas in which the inquisitive are now working.

Certainly one can not foresee or predict the particular new science disclosures of the future. They have usually been unneeded for a while, even after disclosure. In other words, we have to get the assets and then apply them before they possess real value. Judging from history, we can expect continuing changes in engineering development as long as inquisitive men are at work and we can not foresee them any better than men foresaw steam engines. This principle of discovery first and utilization after is the oldest thing in man's history.

I have seen a tiny electric motor running directly by sunlight. A Jules Verne might picture the advantages of every one having a powerful helio-electric center in his back yard, but that is not a fair use of science in this case. It only serves to show how much we still have to learn.

Science to-day is smashing atoms, transmuting them into other elements, transforming matter into energy and discovering new fundamental things, such as the positron, the neutron, the deuton, and now the triton. No one can foresee the applications of this new knowledge, but the electron brought us long distance telephony, radio broadcasting, talking pictures, television and scores of useful automatic controls. Surely from its newly discovered colleagues we may confidently expect in time applications of equal or greater importance.

Since the stone age, men have thought the world was finished, but history shows that only one thing is certain—change.

By Dr. ARTHUR H. COMPTON

PROFESSOR OF PHYSICS, UNIVERSITY OF CHICAGO

THE scientist is society's scout who goes far into nature's new territory and brings back a report of what lies there. Almost every new wave of technological advance has followed upon some important new discovery by these scientific scouts. The studies by Watt and Carnot of the properties of steam ushered in the first great era of mechanical power. The discovery of electromagnetic induction at the beginning of the century of progress which has just passed made possible the electrical industry with the great changes in living which that has implied. In the discovery of electrons and their emission from hot wires was born that vigorous youth, the radio industry. Such examples are sufficient to indicate that with further advances of science new industries may be expected to arise which will change our mode of life, much as our present way of living differs from that of our grandfathers.

Contrary to the thought sometimes expressed that the great finding of physics and chemistry have already been made, there seems no indication that our discoveries have begun to exhaust the possibilities of nature. On the other hand, techniques for making discoveries have been so developed, and the number of trained men carrying on scientific research has so rapidly increased that we may expect the next generation to see more great advances in science even than the last. The direction of science's immediate future is indicated by the lines of study which are just now being emphasized. A telescope mirror of four times the light-gathering power of our present best instrument is being constructed which will enable man to see farther into space than ever before. Great high voltage equipment is almost completed which will form a new tool for investigating the inner citadel of the new

atom where its precious store of energy is hidden. Powerful instruments are being built for observations in different parts of the world to study those mysterious visitors from outer space which we call cosmic rays. The methods of physics and chemistry which have proven so effective in their own fields are being extended to the study of growing cells with striking results.

Our telescopes and spectroscopes have shown us rather definitely the size of our vast universe. It is reasonable to suppose that we shall soon find some knowledge regarding the ancient history of that universe. Has it been in operation forever, or did it start at some more or less definite time in the ancient past? If the latter guess is correct, we may hope to learn the when and perhaps the how of that great beginning. One approach to this question comes through the cosmic rays which have perhaps been coursing through space since the beginning of the world, and may thus carry with them an account of those beginnings we are already making in the laboratory of Madame Curie and elsewhere —artificial radioactive elements. Where will these lead? Very probably to the creation of useful new forms of matter. There is a remote possibility that such experiments may lead to a new store of available energy, and if so, the magnitude of that energy should be tremendous. We do not yet know, however, whether this great store of atomic energy can be put to our use, much less can we suggest how.

In an age when available power is a problem of great importance, the possibility of synthetically preparing chlorophyll, and through its action store in chemically the power from the sun in a more efficient way than can be done through the growth of plants, is an enticing one. It would seem highly probable that physical and chemical methods of making artificial living cells will be developed. Enough progress toward understanding the processes involved has already been made to predict that this further great step is probably in the not distant future. This of course has little direct relation to life in its more complex forms, such as plants and animals. It required millions of years for nature to evolve these organisms; nevertheless, if artificial life in its simplest form can be produced, its significance in supplying man with new powers and in changing perhaps his complete mode of existence can hardly be overestimated.

Perhaps these glimpses into what the future of physics and chemistry may have in store will serve to suggest the great possibilities which are yet ahead. Unless civilization utterly fails us and removes from the followers of science the means whereby research can be carried on we may confidently anticipate a continued and rapid growth of our knowledge of nature and with that knowledge a growth of men's powers.

By Professor ROBERT A. MILLIKAN

CHAIRMAN EXECUTIVE COUNCIL, CALIFORNIA INSTITUTE OF TECHNOLOGY

THE progress of civilization consists merely in the multiplication and refinement of human wants. Leave the human spirit free for the development of science and education and no bounds can be set to the possible fullness of life of the average citizen of the United States in the coming century. But destroy the freedom of that spirit either by the blight of another world war or by the more insidious blight of what Herbert Spencer called the coming slavery—too much stateism—and the dream may be spoiled.

In my own field of physics we seen no end to the road.

By Dr. ARTHUR A. NOYES

DIRECTOR OF THE GATES CHEMICAL LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY

In my own field, chemistry, and in science generally I feel sure that if scientific and industrial research are stimulated and not handicapped there will result in the future as in the past a stimulation of the wants of men and a much greater employment of labor than the unemployment resulting from displacement of old industries. Recent chemical research affords striking illustrations, such as development of light metals of modified steels, the numerous cellulose industries, and most strikingly in the promotion of health and efficiency through biochemical investigations. It is true there is always likely to be a temporary maladjustment of industry and employment which must be broadly handled by industry and the government if necessary. The results of failure to do so must not be attributed, as it is by some persons, to the advance of science, from which our modern civilization has largely resulted, but to industrial social and political failure to meet rapidly new situations.

By Dr. JOHN C. MERRIAM

PRESIDENT, CARNEGIE INSTITUTION OF WASHINGTON

I am in agreement with you regarding the importance of the development of science and industry and a broad vision of policies relating to future progress. An attempt to secure a safe foundation of fact and to develop a clear vision of opportunities for the future represents one of our great responsibilities. May I express my belief in the effort to secure such understanding of our present situation and of the conditions which govern human activities that we may be able to develop policies of the most constructive type and open the way for advance with a minimum of loss and the maximum of advantage for the future.

By Dr. G. H. PARKER

PROFESSOR OF ZOOLOGY, HARVARD UNIVERSITY

Biologically speaking it is fair to say that man's social progress is now only at its beginning and that the two million years that separate us from the caveman mark only the start of human life; the progress of the next two million years is as inevitable as that of the last, and when we have reached this new goal such events as the present depression will have vanished beyond recognition.

By Dr. RAYMOND PEARL

PROFESSOR OF BIOLOGY AT JOHNS HOPKINS UNIVERSITY

I am of the opinion that we are on the threshold of advances in biology generally, and particularly human biology, that will fundamentally alter our outlook. Progress in biology in the next decade, comparable in significance to that in physics in the last decade, may confidently be expected.

Already we know how in the laboratory to increase the power of lower organisms to utilize their available resources in food material and energy for vital processes, such as growth and duration of life from three to ten times over their usual performance with corresponding relative increases in size, longevity, and so forth.

Developments and applications along

these lines are likely to come in the not too distant future. Our greatest need now is for more encouragement and support of research in human biology to make possible a better social integration between human beings in the mass, and discoveries and advances in the industrial field.

By Dr. J. McKEEN CATTELL
EDITOR OF SCIENCE AND THE SCIENTIFIC MONTHLY

SCIENTIFIC research and the applications of science in the course of 150 years have increased fourfold the productivity of labor; they have doubled the length of life. Science has made it possible for each to work at routine tasks half as long as formerly and at the same time to consume twice as much wealth. Fourteen hours of labor, shared by women and children, once provided hovels, lice and black bread for most people, luxury for a few. Seven hours of labor will now supply comfortable homes, warm clothes and healthful food for all. If the resources provided by science were properly distributed—as they will be when we have an applied science of psychology—there is now sufficient wealth to enable all to share in the desirable luxuries that science has created—running water, electric household equipment, telephones, automobiles, radios and the rest—and to enjoy in full measure the most nearly ultimate goods of life—home, friends, things to do, freedom, self-respect.

The applications of science have abolished slavery and serfdom, the need of child labor, the subjection of woman; they have made possible universal education, democracy and equality of opportunity, and have given us so much of these as we have. Science has not only created our civilization; it has given to it the finest art and the truest faith. During the coming century, the advancement of science should be the chief concern of a nation that would conserve and increase the welfare of its people.

By Drs. WILLIAM J. and CHARLES HORACE MAYO
MAYO CLINIC, ROCHESTER, MINN.

THE discoveries of Pasteur and Lister have resulted in the elimination of contagious disease through preventive medicine. The average life of mankind in the time of Queen Elizabeth was twenty years. To-day the average is fifty-eight years for man and sixty-one for woman, who is biologically more important.

As the life span has increased, diseases of later life, that is, cancer and diseases of the heart and the blood vessels, have taken the major toll. Remarkable advances have been made by new methods not only in the diagnosis of cancer, but in its cure, so that the percentage of cures in recent years has been doubled. Marvelous progress has been made in a better understanding of diseases of the heart, the blood vessels and the kidneys, which to-day have been brought into the field of preventive medicine.

Much of this new knowledge has been brought about by better understanding of heredity in relation to constitutional liabilities. The scientific discoveries of to-day are becoming the handmaidens of the medicine of to-morrow.

Seventy-five per cent. of the energy produced in the human body is not under conscious control. Certain small inconspicuous glands of internal secretion, which act through the sympathetic nervous system when affected, are responsible for many of the physical and mental disorders of man.

These recent discoveries in medicine are leading to astonishing results, and give a prospect that the life of man will soon reach the Biblical promise of three score and ten.

The people of America base their hopes of sound democracy on education, so that government which now is controlled too largely by emotions may be more intelligently administered. The medical profession is one of the great forces in bringing about social progress.

By Dr. RAY LYMAN WILBUR

PRESIDENT OF STANFORD UNIVERSITY

Far from being finished, the human family and our social organization are not even started. We have uncovered the geography of the world and are beginning to put various universal laws into service. Every time our research workers develop a new fact, new possibilities of advance are opened up. Our nation has benefited more than any other from discoveries and inventions. This is a period of readjustments following a great war. If we can preserve our liberties and retain for the individual his freedom of action and exploration into the unknown, we will find new ways to go forward.

By ALFRED P. SLOAN, Jr.

PRESIDENT OF THE GENERAL MOTORS CORPORATION

It is tremendously encouraging to be assured by men who speak with authority that science is ready to show the way to greater industrial progress and thus to higher standards of living and greater opportunities for all.

In calling together the leaders of science and industry for our meeting on May 25, we asked two questions:

"What is to be the progress of science and industry during the next decades?"

"Is there any logical reason to assume that progress is to be halted at this particular point in our development?"

The contributions of these men who are in actual contact with the problem show that the world is in no sense finished; that great thought and effort is being expended and real progress effected toward better things that affect all phases of our daily lives. They confirm the belief that the very progress of the past insures still more progress in the future and at an accelerated rate, if we have the breadth of view-point and the knowledge of the facts to properly manage our affairs.

The assurance of these leaders that scientific progress is not a thing of the past is a challenge to America not to be satisfied with a static position either in our thinking or in our actions. It is a challenge to us to continue to encourage and reward constructive efforts and to retain the principles which have made this country what it is.

If we accept this challenge we will accelerate the processes of natural recovery that we all believe are very definitely in the making throughout the world. We will build a sound foundation for a still greater future.

MAKING THE GLASS DISK FOR A 200 INCH REFLECTING TELESCOPE

By Dr. GEORGE V. McCAULEY
CORNING GLASS WORKS, CORNING, N. Y.

To the scientist and research worker the casting of a glass disk for an astronomical telescope must seem a very simple task. One constructs a mold the size of the mirror, an annealing oven which will contain the mold when filled with glass, melts a sufficient quantity of glass in some sort of furnace, transfers the molten glass into the mold, places the mold with its load of glass into the annealing oven, and finally, depending upon the size of the article and the known annealing constants of the glass, controls the rate of cooling of the glass in the annealing oven until room temperature is reached when the glass may be removed as the desired mirror blank. At least that is how it appeared to the laboratory staff of the Corning Glass Works when the problem of making a 200 inch reflector for the California Institute of Technology was placed before them by the observatory council of that institution late in 1931. This attitude may have been born of ignorance of the dangers ahead or of a complete lack of any traditional ideas in the minds of that organization as to the proper methods for casting large telescope disks. At any rate those entrusted with the task had complete confidence in the ability of the laboratory and engineering facilities at their command to succeed. With this confidence, and armed with a full knowledge of the melting, working and annealing properties of the glass they could see no great obstacles.

The detailed accomplishment of the various steps in the process belongs more precisely to the realms of engineering than to those of the pure sciences. Since, however, the purpose of the whole endeavor was to produce a tool for scientific research, an account of the engineering problems encountered and of the regular glass industry practises employed will be of interest to all.

The forming of glass objects by melting broken pieces of glass at low temperature in a mold of ceramic materials dates from antiquity. It is not possible, however, with all types of glass to secure articles by this method clear of objectionable gas bubbles resulting from entrapped air and unsightly wisps of crystallization marking the original exposed surfaces of the individual pieces of glass. These defects are particularly noticeable with the low expansion borosilicate glasses, of which it was desired that the 200 inch disk be made. It was evident, therefore, that the disk would have to be cast from the molten state by transferring the glass by one of the many known methods of the industry from a melting unit to a suitable mold.

A mold material suitable for casting glass must possess certain properties. In the first place, it must have sufficient strength to sustain the load of the glass. Secondly, a certain degree of refractoriness is essential to withstand the temperature of the molten glass without fluxing. Thirdly, sufficient insulating qualities are needed to prevent too rapid cooling and hence excessive tensile stresses in the parts of the glass in contact with the mold during the forming process. And finally porosity of the mold serves the usual purpose in casting any molten material and especially a

highly viscous one. Without outlets for entrapped air to escape through the mold bubbles form. These increase in size by virtue of the high temperature of the glass and form "blow holes" in the casting.

The research necessary to perfect a mold material with these properties, as indeed was the case for many of the problems involved, consisted largely of finding a commercial product, which approximated the requirements and then of applying the needed modification to make it work. The mold was thus made from a commercial high temperature insulating brick which admirably possessed the qualities of strength, porosity and insulation. It was also soft enough to be sawed readily in any desired shape. By applying a simple coating in the form of a thin wash of silica flour its refractoriness was increased and to its surface was given friability which subsequently insured easy removal of the glass from the mold and incidentally prevented the evolution of small bubbles of gas from the surface of the mold after the prolonged heating following the casting operation.

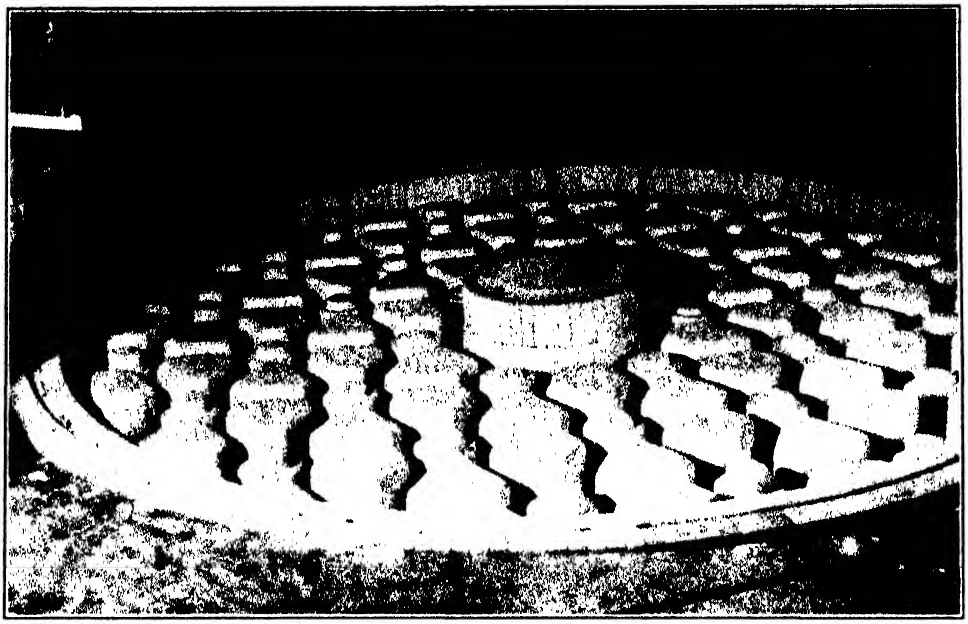
The making of the mold was somewhat complicated by a desire to obtain the requisite rigidity in the large disk with reduced weight. In accordance with the age-old tradition of making the mirror thickness one sixth its diameter, the 200 inch mirror would have been nearly thirty-four inches thick and would have weighed over forty tons. While the astronomers are very anxious for increased diameter of mirror they do not want the increased weight that goes with it. To meet these demands a ribbed structure was decided upon. This gave the required rigidity with an over-all thickness of twenty-five inches and a weight of twenty tons. The general form of this structure as seen from photographs of the 30 inch flat, 60 inch convex and 120 inch test flat which has already been cast and annealed is one at which the novice might be expected to arrive with compass and paper after learning that a regular hexagon can be inscribed in a circle with the side of the hexagon equal to the radius of the circle.

The form, however, besides suggesting an elementary theorem in plane geometry, serves several useful purposes from the standpoint of glass casting and mechanical strength. The straight ribs intersect the round ones, forming the points of support at right angles, and hence acute angles around which stresses may be high are avoided. Also the straight ribs with the points of support are in straight lines which makes for continuous ribs across the disk in three directions.

In making the mold masons became pattern makers, using blocks of ceramic material instead of blocks of wood. The cores for the mold were formed by cementing together shapes cut from bricks. With the cores fashioned they were located on the floor of the mold by means of a wooden template comprising one sixth of the area of the mold. These cores were then anchored in place with a metal plate and rod at whose lower end a spring under compression sufficed to take up the differential expansion between anchor and core during the pouring process.

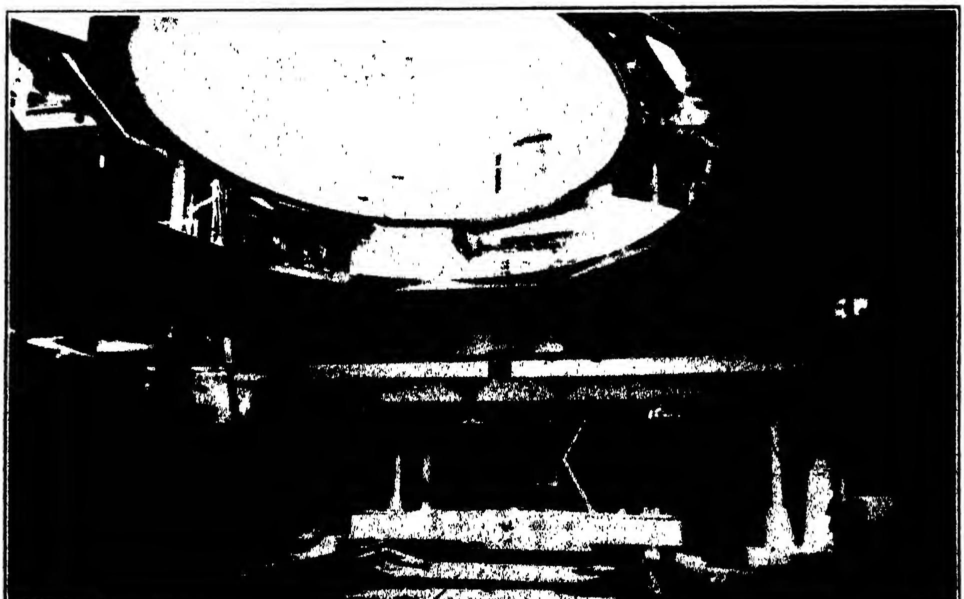
The annealing oven, while intricate in detail, is after all quite simple. It is in reality a "black body" enclosure whose walls are maintained at a uniform temperature by a system of uniformly distributed electric heating units controlled by thermocouples in conjunction with automatic temperature controllers. A simple mathematical calculation suffices to tell the power input required and hence the size of heating units to maintain a given inside temperature for a fixed degree of insulation.

To keep the power consumption of



MOLD FOR 200 INCH DISK

THE LARGE CENTRAL CORE PRODUCES THE 40-INCH HOLE REQUIRED IN THE CENTER OF THE DISK. THE REMAINING SYSTEM OF CORES PRODUCES THE RIBBED STRUCTURE TO THE DISK.



ABOVE IS THE INTERIOR VIEW OF THE POURING FURNACE

BELOW IS THE 60-TON SCREW HOIST FOR TRANSFERRING THE DISKS FROM POURING TO ANNEALING FURNACES.

annealing low the insulation of the kiln was of course given considerable attention. In its entire construction no metal passes unbroken from the interior heated portion of the outside, although the kiln, weighing many tons, is suspended by rods from an overhead steel structure to permit the insertion of the disk with its mold from below. All suspension rods are broken with an insulating medium under compression at the break. Thus the circular vertical wall and the roof of the kiln are suspended from above with fixed electrical connections to the source of power. The floor of the kiln is built under the mold on the table of a sixty-ton screw hoist with flexible electrical connections to the power supply. When lifted into position the side wall of the lower part of the kiln telescopes with that of the upper into a ring of insulating powder and completely seals the glass in the center of a "black body" furnace.

The method one employs for transferring the molten glass from a melting unit to the mold depends somewhat on circumstances of location and on the nature of the glass. When one pours a highly viscous liquid such as the proverbial "molasses of January" from the barrel to the pitcher one entraps bubbles of air in the pitcher and these do not escape readily because of the viscous state of the molasses. And so it is with the pouring of molten glass. It is very difficult to avoid introducing these bubbles; hence some provision should be made for their removal. In doing this one has the choice of either transferring the glass to the mold very quickly at a high temperature so that the viscosity of the glass after casting is still low enough to permit bubbles to rise, or to provide means for reheating the glass in the mold during and after pouring. The first plan becomes increasingly difficult as the quantity of glass to be transferred becomes greater and as we pass from the more fluid crown glasses to the viscous borosilicates because of the enormous quantity of heat that must be dissipated quickly and the increased viscosity which retards the rise of bubbles under the action of gravity. Consequently in the making of the 200 inch disk recourse was had to the second plan above.

A round furnace structure or "igloo," as it came to be called, was suspended from an overhead carriage, in a manner such that the mold could be elevated with its upper rim in contact with that of the underneath portion of the structure above. When sealed in this position the mold and hood above constituted a closed furnace which could be heated with many gas burners around its periphery to a temperature of 1350° C. This enabled any desired temperature to be maintained while the glass was being transferred to its mold and permitted subsequent heating after the mold was filled to cause the escape of all entrapped gas bubbles.

For the construction of the pouring furnace the same light, refractory insulating brick was employed as was used in the mold. This kept the suspended weight on the overhead carriage to a minimum and insured the attainment of the desired temperature for the removal of bubbles.

The carriage support for the pouring furnace provided for moving it out of the way while building the mold on the table top of the screw hoist, which likewise was movable on its carriage on the floor below in a direction at right angles to the motion of the pouring furnace carriage. Thus after transferring the glass to its mold and reheating to free from bubbles it was an easy matter by pressing a button to lower the fifty-ton load of glass, mold and bottom portion of annealing kiln, shift the whole assembly laterally with the hoist carriage, and raise into position inside the annealing kiln.

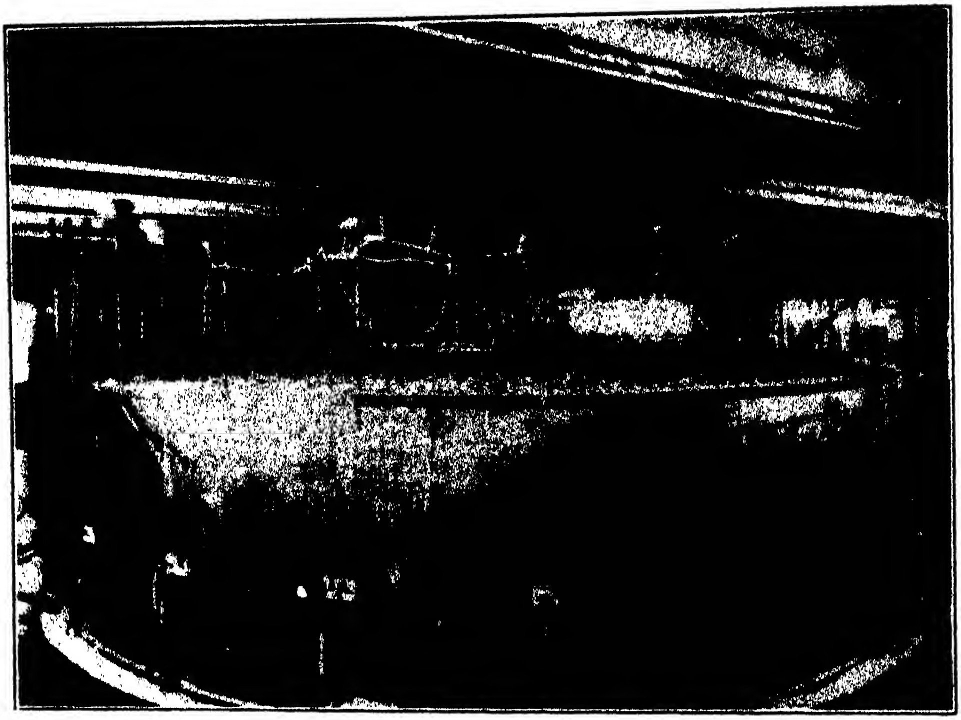
The large quantity of molten glass re-

LADLE OF MOLTEN GLASS ON WAY TO MOLD

THE LADLE HANGER, TROLLEY AND BALANCING CLEVIS ARE CLEARLY SHOWN. OVER THE RIM OF THE LADLE BOWL IS THE EDGE OF CHILLED GLASS THAT SERVES AS AN ANCHOR FOR HOLDING THE "LADLE SKIN" WHILE POURING.

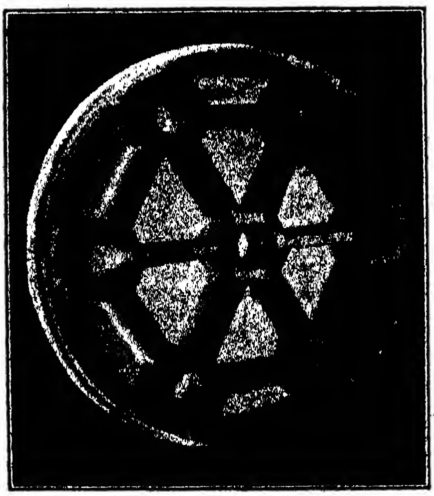
POURING FURNACE OR "IGLOO"

USED FOR CASTING THE 200 INCH DISK. THE LADLE OF GLASS IS SHOWN IN THE PROCESS OF POURING INTO THE 200 INCH MOLD.



ASSEMBLED VIEW OF THE ANNEALING KILN

WHILE THE 120 INCH DISK WAS IN PROCESS OF COOLING. THE SAME KILN IS BEING USED FOR THE 200 INCH DISK.

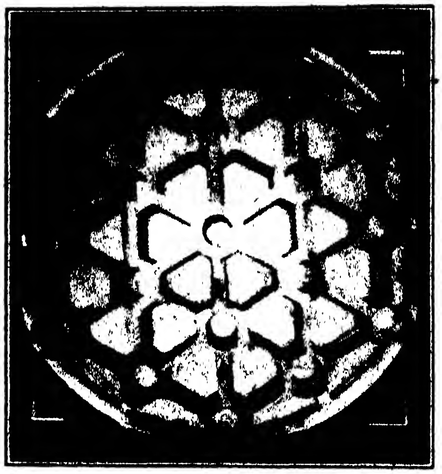


30 INCH DISK CAST ON MAY 1, 1932 REMOVED FROM THE ANNEALING KILN ON JUNE 1, 1932.

quired is best supplied from a melting unit known to the glass industry as a "tank." This is nothing more than a large pool of molten glass contained by walls of refractory clay over which a brick structure closes the space into which fuel is burned as in the open hearth furnace of the steel industry. It is possible in this manner to secure a large volume of glass of more uniform physical properties than if melted in many small pots, as has been the custom of the past in making telescope disks.

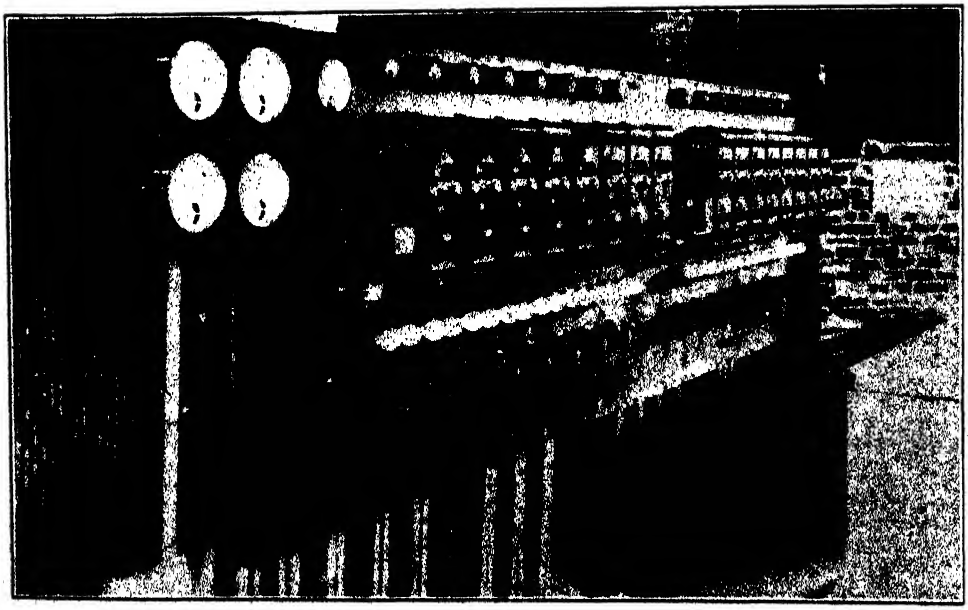
Many ways, tried and untried, might be used for conveying the glass from the melting unit to the mold. In the actual making of the 200 inch disk, the method of ladling was selected as the one best suited to the particular location, as costing less to install and operate for

the manufacture of a single disk and as having associated with it the least element of chance. This is in part an old method employed in the manufacture of window glass and was known to work well. In this process large iron ladles capable of holding approximately 750 pounds of glass are employed. A swivel hanger on a trolley carries the ladle on an overhead track for easy transference from tank to mold. At the lower end of the hanger is a second trolley wheel running in a clevis attached to the ladle handle and extending parallel with it. This clevis permits the point of suspension of the ladle system to shift with the load. When empty, balance is obtained at the far end of the clevis, and when loaded, at the near end with respect to the bowl of the ladle.



60 INCH DISK CAST ON JULY 13, 1932 REMOVED FROM THE ANNEALING OVEN ON SEPTEMBER 19, 1932.

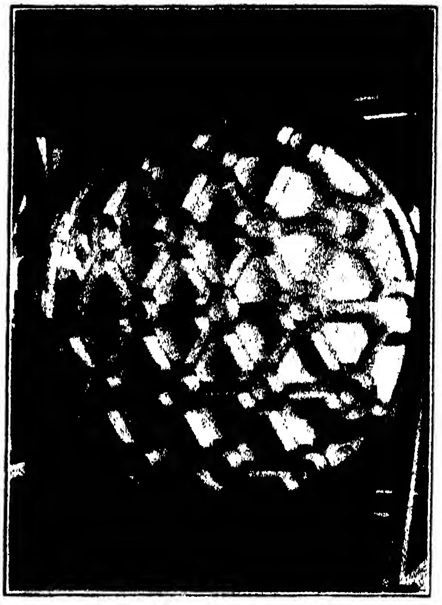
In filling the ladles attention must be paid to the viscous nature of the glass. Passage of the ladle rim through the glass can not be hurried if one wishes to fill the ladle with a single and simple dipper motion. The ladle enters the tank in an inverted position after being thoroughly cooled with water. It is then dipped down and a slowly rotating motion imparted about the handle as an axis turning in bearings in the balancing clevis. One edge of the ladle rim thus cuts through the glass and cups out that portion of glass which fills it. The ladle



SYSTEM OF AUTOMATIC CONTROLLERS THAT MAINTAIN THE TEMPERATURE DURING THE ANNEALING PROCESS

is then returned to its horizontal position and withdrawn from the tank with the point of suspension automatically changing in the clevis. The surplus glass adhering to the entering rim of the ladle during filling is now removed, leaving enough chilled glass projecting over the rim to act as an anchor for holding the viscous "ladle skin" next to the metal on the ladle while pouring from the other rim in the mold. This "ladle skin" is then returned to the far, or filling, end of the tank to assist in maintaining the level of the glass in the tank as near the initial point as possible.

The regulated cooling or "annealing" of the glass disk is largely automatic. Temperature controllers, ten in number, hold the temperature at ten scattered points in the inner surface of the kiln at whatever value the operator sets the dials. A constant temperature of 500° C. will be needed for fifty days to relieve stresses. By decreasing the dial setting of one after the other of these instruments at three-hour intervals, the temperature of the entire kiln is then reduced one degree centigrade in thirty hours. Thus the disk is gradually cooled to room temperature when it will be ready for inspection and shipment.



120 INCH DISK CAST ON JUNE 24, 1933 REMOVED FROM THE ANNEALING KILN ON DECEMBER 10, 1933.

With disks of 30, 60 and 120 inches in diameter successfully cast and annealed with ribbed structures and the glass for the 200-inch mirror cast into its mold, it should now seem certain that even larger disks could be made by employing the methods and equipment outlined here.

THE PROGRESS OF SCIENCE

PRESENTATION OF THE MEDALS OF THE NATIONAL ACADEMY OF SCIENCES

One of the outstanding events at the spring meeting of the National Academy of Sciences is the award of medals and honorariums in recognition of noteworthy accomplishments in research. The National Academy has nine "medal funds," and on the evening of April 24 it conferred honors upon five distinguished men of science. President W. W. Campbell, who gave the address at the dinner at which the medals were presented, emphasized that "the academy's ability to confer honor upon its members and others of high achievement proceeds from the honors conferred upon the academy by its members through their accomplishments in the advancement of knowledge."

Short presentation addresses by members of the academy accompanied the award of the medals. These, in part, are reproduced here:

The Agassiz Medal

The Agassiz Medal was awarded to Bjorn Helland-Hansen, of the Geofysiske Institut, Bergen, Norway, in recognition of his work in physical oceanography and especially for his contributions to knowledge of the dynamic circulation of the ocean. In his presentation address, Dr. Henry B. Bigelow, curator of oceanography, Museum of Comparative Zoology, and professor of zoology at Harvard University, and chairman of the Committee on the Agassiz Medal award, said:

In every advance in oceanography, certain names stand forth. And when scientific accounts are cast we find Helland-Hansen—often linked with his one-time master and life-long associate, Fridtjof Nansen—a key name in developments that have become integral in modern science of the sea. It was Helland-Hansen and Nansen who first clearly appreciated and published to the scientific world the fact that the oceans are so uniform over great distances and over great ranges of depth that only from the most precise measurements and determinations can the true physical characteristics of the high seas be learned. Nor was this an advance in technique only, for practise and theory marched hand in hand. And in 1909 Helland-Hansen and Nansen jointly published their classic study of the Norwegian sea, in which they so accurately traced its essential physical characteristics, with the ebb and flow of the ocean currents, as to make this at a stroke the best known part of the ocean, and their monograph a model for all the regional studies in descriptive oceanography that have followed it. In 1903 we find Helland-Hansen and Sandstrom (then young men) developing a simple and workable method by which Bjerkenes' theoretic analysis might be applied numerically to conditions as actually existing in the sea, with calculation of dynamic currents in the waters between Norway and Ice-

land as a test case. Later came Bjerknes' monumental volumes on "Dynamic Meteorology and Hydrography," following which, and with gradual developments in mathematical method (in which Helland-Hansen's touch is repeatedly to be seen) many dynamic studies have been made for different parts of the sea. The current surveys made on the Grand Banks by the International Ice Patrol Service are a direct result of Helland-Hansen teachings. But again it awaited Helland-Hansen, working with Nansen as so often, to apply dynamic calculation to accumulated data for a great ocean, and so to make clear the circulatory tendencies existing on so broad a scale throughout the whole mile-deep mass of water.

The Elliot Medal for 1930

The Elliot Medal and Honorarium of $200 for 1930 was awarded to Dr. George Ellett Coghill, professor of comparative anatomy and member of the Wistar Institute of Anatomy and Biology, in recognition of his work, "Correlated Anatomical and Physiological Studies of the Growth of the Nervous System in Amphibia." Dr. Ross G. Harrison, Sterling professor of biology at Yale University and chairman of the Committee on the Elliot Medal, in conferring the honor upon Dr. Coghill, made the following statement concerning his work.

Embryologists have dealt for the most part with the development of organic form, disregarding the fact that with it goes hand in hand the development of activities or function. The correlation of these two phases of development, because of the difficulties involved, has not received the attention it merits. It is precisely in this field that Dr. Coghill's pioneer work has won for him a place of high distinction. The amphibian embryo, still in its envelopes, shows the first muscular movements when its external form begins to shape itself and head, trunk and tail are easily recognized. The character of these movements rapidly undergoes a series of changes during the remainder of embryonic life until at hatching they are quite complex and the young animal is able to shift for itself. The progressive changes in reaction have been followed by Dr. Coghill step by step in individual embryos, and at each stage cases taken immediately after their reactions had been tested were preserved and studied microscopically. In this way the actual state of differentiation of the nervous system in each individual has been correlated with its behavior. It has been found that a progressive differentiation of nerve cells, fibers and sense organs takes place, preceding by a short interval the initiation of the corresponding reactions. Associated with differentiation, but in a certain sense antagonistic to it, is the process of growth, the study of which has required the counting of thousands of cells and charting their positions in the spinal cord and brain at various stages of development. This has involved an immense amount of painstaking work which would all have been to little purpose, had the task not been approached by a man of broad knowledge and subtle insight. From all this has developed a new conception of the origin of nervous function. At no time does the nervous system work as a collection of independent reflexes, which later become integrated. On the contrary, at each stage it functions as a whole, expanding from stage to stage, and as development proceeds, various partial functions arise within it as more or less discrete reflexes. These investigations of Dr. Coghill will have a lasting influence in psychology and physiology as well as in embryology.

The Elliot Medal for 1931

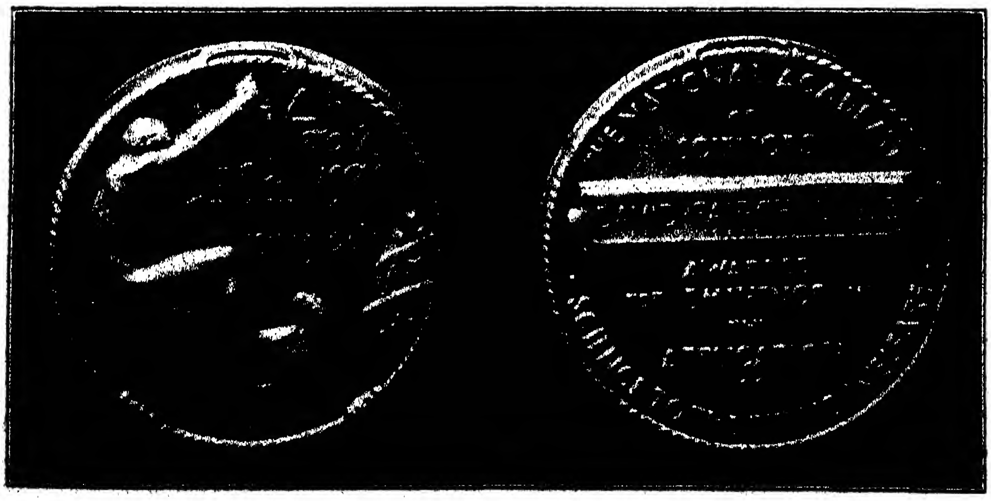
The Elliot Medal and Honorarium of $200 for 1931 was awarded to the late Davidson Black. Dr. Black, a native of Canada, was professor of anatomy at the Peiping Union Medical College, Peking, China, at the time of his death on March 15, 1934. This award was made in recognition of his work on an adolescent skull of *Sinanthropus pekinensis* in comparison with an adult skull of the same species and with other hominid skulls, recent and fossil. In giving the reasons for the award to Dr. Black, Dr. Henry Fairfield Osborn, honorary president of the American Museum of Natural History and a member of the Committee on the Elliot Fund, said:

> The honor falls to me of describing his share in the discovery and his unique part in the description according to the very highest standards of modern prehistoric anthropology, of the Peking man, *Sinanthropus pekinensis*, which has already become a classic. These additions to the great and highly diversified family tree of man were discovered in the years 1926 to 1929 in a cave fissure deposit about thirty-five miles southwest of Peiping, a deposit of very hard limestone known for many years to yield rich fossil remains of the early Pleistocene period estimated at approximately one million years ago. Infinite patience and infinite technical skill were required to free these fragile specimens from the matrix and a very high order of anatomical knowledge to correctly interpret them. From 1926 to 1934 Davidson Black has devoted his entire strength, energy and skill to exposing and examining this series, which yielded one type lower molar (1927), two adult or nearly adult skulls, six parts of adult and immature mandibles, various separate teeth, limb and girdle fragments, a wrist bone, phalanges, etc. To these remains the scientific name most aptly applies—"the man of China found near Peking." In a long series of brilliant publications, culminating in the monograph of 1931 for which this Elliot Medal is given, "On an Adolescent Skull of *Sinanthropus pekinensis* in Comparison with an Adult Skull of the Same Species and with Other Hominid Skulls, Recent and Fossil," all the characteristics of these specimens were carefully set forth, figured and described, with the result that Peking man is shown to be extraordinarily similar to the Trinil man (*Pithecanthropus*) in its form and brain size and structure, while differing most widely from the Piltdown man of Sussex not only in the beetling forehead but in the relatively massive jaw. Thus its closest affinity is to the Trinil cranium, while in its grinding tooth structure thoroughly human or Neanderthaloid.

The Public Welfare Medal

The Public Welfare Medal was awarded to Dr. David G. Fairchild, formerly of the U. S. Department of Agriculture, Washington, D. C., for his exceptional accomplishments in the development and promotion of plant exploration and the introduction of new plants, shrubs and trees in the United States. Dr. Henry H. Donaldson, member of the Wistar Institute of Anatomy and Biology and a member of the Committee on the Public Welfare Medal award, who made the presentation address, said:

> This medal is awarded for eminence in the application of science to public welfare. The award was made to Dr. Fairchild: For his ex-



ceptional accomplishment in the development and promotion of plant experiments; for the introduction of new plants, shrubs and trees into the United States; and for his services of a working lifetime, which have contributed to the easy availability of some of our finest fruits and vegetables, thus adding to the wealth of the nation by opening new lines of activity to American farmers. It is to be noted that this award is a recognition of ideal aims guiding long-continued scientific activity directed to the public good.

The Charles Doolittle Walcott Medal and Honorarium

The Charles Doolittle Walcott Medal and Honorarium of $1,350 was awarded to David White, senior geologist at the U. S. Geological Survey, in recognition of his work, published and unpublished, on the Precambrian algae life of the Grand Canyon of Arizona. In his presentation address, Dr. Charles Schuchert, chairman of the board of directors of the Walcott Fund, told how, as a young fossil collector, Walcott's curiosity was piqued by finding some drift rock containing strange organic remains. Eleven years later he found identical ones and learned that they were of "primordial time." His interest thus strongly aroused led him to become the world's authority on the life and history of Cambrian times. Under Major Powell in 1882, he again found "primordial" fossils and the first traces of Precambrian life. "No one has yet found in abundance the Precambrian life that Walcott so earnestly sought," Dr. Schuchert continued, "and it was with the idea of stimulating others to realize his unfulfilled ambition that Mrs. Walcott, who helped her husband collect many a hundredweight of Precambrian algae, presented to the National Academy the fund which yields the medal and honorarium to be presented here to-night.

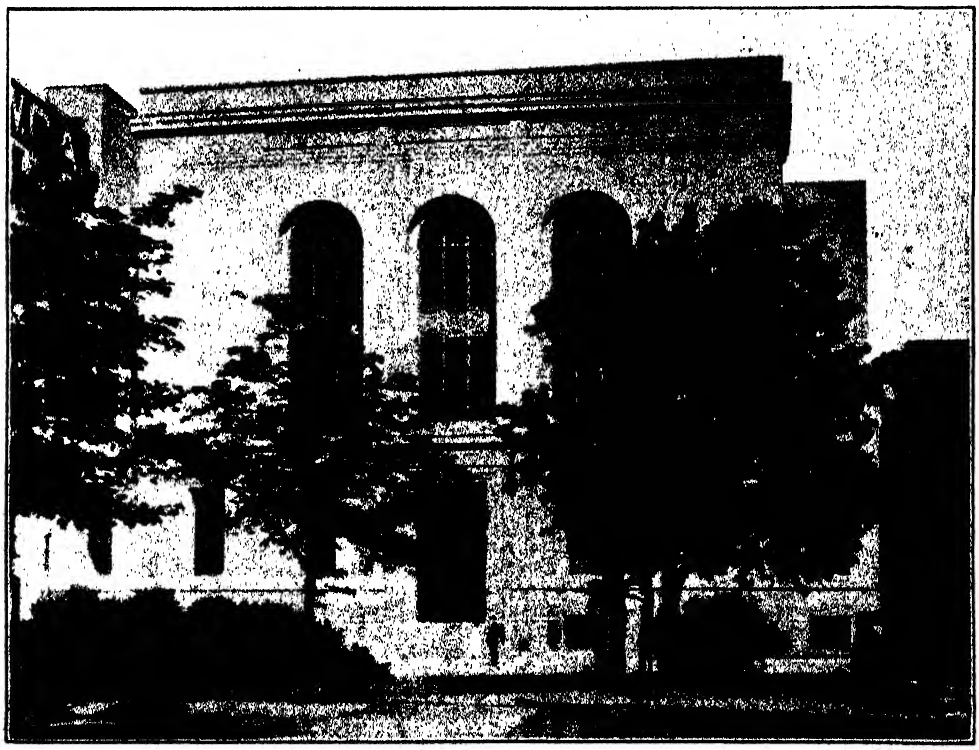
In the upper walls of the Grand Canyon occur Carboniferous land plants, which have formed the basis for one of the classics of paleobotanical literature, "Flora of the Hermit Shale, Grand Canyon, Arizona," written by David White, whose extraordinary knowledge of the coal floras has played no small part in the unraveling of our late Paleozoic stratigraphy. In the course of his work in the canyon, Dr. White's attention had been especially directed to the traces of Precambrian organisms which had been found there by Walcott and others, and which had been rendered even more significant by subsequent discoveries of similar forms in the Belt series of Montana. For several field seasons he studied with great care the detailed environment of these ancient fossils, and collected them in abundance, and he has demonstrated, with his customary thoroughness, that the deposits in which they were entombed were those of a shallow sea, and not, as had been supposed, those of a fresh-water lake. What is even more significant, he has, by new methods of laboratory research, both of a physical and a chemical nature, revealed the microstructure of these remains and established them definitely as algae. His preliminary results have already appeared in a number of papers, and his monograph, to be published by the Carnegie Institution of Washington, will bring together his studies on a great mass of material, much of which was collected by Walcott. His researches thus mark a decided step forward in our knowledge of Precambrian life.

THE PRODUCTS OF INDUSTRIAL CHEMISTRY AT THE NEWARK MUSEUM

THE dramatic manner in which the products of the chemist's test-tubes are supplanting the familiar materials of the world about us is the subject of an exhibit which the Newark Museum opened to the public at the end of March under the title "Miracles of Chemistry: New Discoveries for Industry and the Home." This is the twentieth in a series of industrial exhibits which the Newark Museum has presented dramatizing the achievements of the industries of its community, but because of its scope and timeliness has already attracted wide interest.

The exhibit which fills the entire second floor of the museum and part of its first floor has been planned to reveal the many ways in which chemistry has affected every-day life, so that the average person may be led to appreciate the tremendous and vital rôle which chemistry plays in the modern world. It was considered particularly appropriate to present such an exhibit in the Newark Museum because chemistry comprises the largest industry of New Jersey and because of the hundreds of new chemically created products, such as the plastics, the rayon and other synthetic textiles and new metals, which have found a place in modern life.

In planning the exhibit, the museum had the active assistance of a number of men and institutions prominent in the field. These included Dr. William T. Read, of Rutgers University; Dr. Edward C. Worden, of the Worden Laboratory and Library; Dr. John H. Schmidt, chairman of the North Jersey Section of



THE NEWARK MUSEUM

the American Chemical Society; Williams Haynes, author and editor of chemical publications; the New Jersey Agricultural Experiment Station, and others.

More than four thousand objects, lent by approximately 100 firms, are on display in the exhibit, all of which relate to the history or background of industrial and research chemistry. A rare and interesting collection of old books and prints dealing with the medieval alchemists and the early pioneers of chemistry, which have been lent chiefly from the University of Pennsylvania's Edgar Fahs Smith Memorial Collection, is shown in the opening section of the exhibit. Here are also seen in interesting contrast an assemblage of some 250 new chemical products of commercial value which have been developed since 1931. These "children of the depression" are eloquent testimony of the unflagging persistence and ingenuity of the chemist in seeking new, better and cheaper ways of providing the necessities of life. Plastics, dyes, perfumes and food materials are found among these

newest chemical creations. Colorful background to this part of the exhibit is given by a display of a striking selection of the new synthetically produced textiles.

On the stairways leading up to the second floor are cases showing the chemical processes involved in the manufacture of soap, sulphur, radium and aluminum.

Symbols of the chemist's most familiar operations and graphic illustrations of the basic theories of the science are seen in the south entrance to the second floor of the museum's exhibit. Adjacent to this section is a demonstration laboratory, fully equipped for performance of simple and striking experiments. The laboratory is manned by four professionally experienced chemists, headed by Emil W. Roth, a former member of the chemical faculty of the University of Heidelberg, whose duties include the performance of the demonstration experiments and the conduct of groups about the exhibit.

Upon information supplied by Dr. Read the next part of the exhibit is devoted to summarizing the facts concerning New Jersey's chemical industries. The state has an annual output of approximately $770,000,000 in silks, rayons, paints, varnishes, dyes, synthetic leathers and other chemically produced goods, the exhibit points out by means of large charts. Second only to New York, which exceeds it by virtue of the nitrates produced at Niagara Falls, New Jersey has an annual output more than twice as large as the chemical exports of Germany.

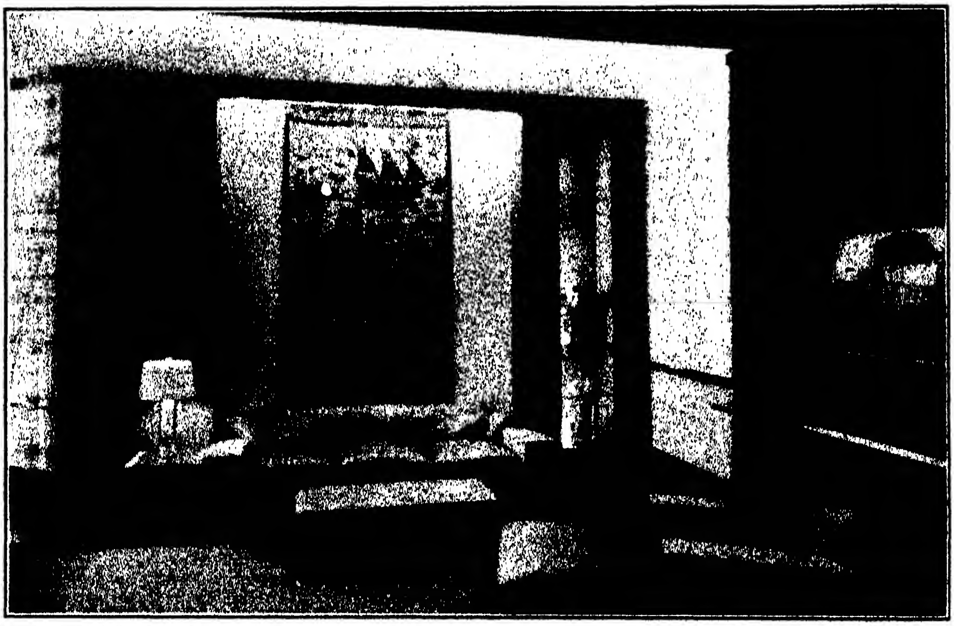
Sections devoted to treasures unlocked from coal and from cellulose follow next. In the coal section are displayed the plastics, the explosives, medicines, dyes and perfumes and other derivatives, while the story of the rayons reveals how, by studying the physiological processes of the silkworm, the chemist has produced a wealth of new materials. The New Jersey Agricultural Experiment Station at New Brunswick has contributed displays concerning the chemistry of agriculture in the next section, while nearby is a section on the chemistry of foods and the story of vitamins and the preservatives.

Perhaps the most dramatic revelation of the many ways in which chemistry has invaded the home has been made in the handsomely furnished living room, designed and decorated by Paul T. Frankl, the well-known interior deco-

rator of New York City, in which chemically created, man-made materials have been employed practically throughout. From a table and desk of Formica with stainless steel supports, to rayon curtains and a synthetic fabric upholstery, and waxed linoleum on the floor, the room gives dramatic proof of the omnipresence of the products of the test-tubes. A kitchen completely equipped, from stainless steel sink to copper pots and enamel kettles by chemically treated materials, is another illustration of the importance of chemistry in the home.

A catalogue entitled "Chemistry Changes Our World" has been published as a guide to the exhibit. In the preface, Miss Beatrice Winser, director of the museum, explains the policy. A popular and entertaining article by Williams Haynes, the well-known writer on chemical subjects, is also part of the catalogue and contributes materially to its value. The exhibit, "Miracles of Chemistry," will continue at the Newark Museum until the end of June.

RUSSELL NEWCOMB



THE "CHEMICAL" ROOM

THE MANNER IN WHICH THE PRODUCTS OF THE CHEMIST'S TEST-TUBES ARE SUPPLANTING THE FAMILIAR MATERIALS IN THE HOUSE IS ILLUSTRATED IN THIS MODERN LIVING ROOM, WHICH IS PART OF THE EXHIBIT. NEARLY EVERY ARTICLE OF FURNISHING IS CHEMICALLY PRODUCED. THE DESK AND TABLE TOP ARE OF A MOLDED PLASTIC OF A LUSTER AND SMOOTHNESS ESPECIALLY ADAPTED TO THE PURPOSE. THE CURTAINS ARE OF RAYON MATERIALS, THE HANGINGS OF AN ITALIAN BATIK WHICH IS ENTIRELY CHEMICALLY PROCESSED. THE WHITE LEATHER COVERINGS OF THE FURNITURE ARE TREATED WITH A CELLULOSE VARNISH TO MAKE THEM WASHABLE.

THE DROUGHT OF 1934

By the close of May, 1934, the most extensive drought in the climatological history of the United States had developed in the central valleys, the Lake region and the Northwestern and Western states. In fact, deficiencies in moisture, ranging from unprecedented dryness over large areas to a decided need for rain in others, was prevalent by the first of June over approximately three fourths of the United States from New York, western Pennsylvania, West Virginia and central Tennessee westward to the Sierras of California and the Cascade Mountains of Washington and Oregon.

In the Northwest the serious shortage in sub-soil moisture and surface water supplies is the result of an accumulated deficiency in precipitation covering several years. In fact, the general rainfall trend in this area has been downward for about a quarter of a century, culminating in the present drought. Every one of the past five years, up to 1934, had less than normal rainfall and the amounts for the first five months of the present year have been the smallest of record in most northwestern sections.

From this northwestern area the drought spread westward, southward and eastward to the Appalachian Mountains on the east, Tennessee, northern Arkansas and Texas on the south, and the Great Basin on the west. The 1930 drought spread from the East-Central states westward to the central valleys, and at the same time much of the area farther west had abundant rainfall.

The 1934 drought is very unusual in several respects. Seldom does a severe drought begin so early in the year and in no other case of record has one at any time covered such an extensive area.

May was extremely dry, the Ohio Valley and Lake region having less than one fourth to a little more than a third of normal rainfall for the month. It was the driest May of record in Ohio, Indiana, Illinois, Iowa and South Dakota, and the second driest of record in Kentucky, Minnesota, Nebraska and Montana. For example, the average rainfall in Ohio this month was considerably less than an inch, and the previous driest May of record had twice as much.

It was the driest spring (March–May) ever known in both the Dakotas, Minnesota, Nebraska, Iowa and Illinois, and the second driest of record in Ohio, Indiana, Wisconsin, Missouri and Kansas. North Dakota had little more than an inch and a quarter of rain during the three spring months; the previous low record—2.15 inches in 1901—is nearly three fourths greater than this.

Considering an entire year, from June, 1933, to May, 1934, it was the driest similar period of record in Indiana, Illinois, Missouri, Iowa, Wisconsin, Minnesota, both Dakotas and Nebraska, and the second driest in Ohio and Michigan.

Extremely high temperatures during May in the interior valleys and the Northwest intensified the effects of the scanty rainfall; not only on a number of occasions were the previous high May records of temperature broken, but over considerable sections it was the warmest May ever known.

From our knowledge of climatology there is no reason to believe that the 1934 drought in the Northwestern states, where most serious, constitutes a permanent change to desert-like conditions in that area. We know there have been major climatic changes in geologic times, and that large areas of the United States have moisture conditions at present differing greatly from those prevailing a great many centuries ago, but certainly no major permanent change in climate has taken place within the last few years.

On the contrary, our longest rainfall records indicate that the 1934 drought in the Northwest is but what may naturally

be expected to occur at comparatively long intervals of 30 to 40 years. These records show that quite similar periods of years, with markedly deficient rainfall, covered the ten years ending with 1864 and again the ten years ending with 1894. About midway between these were a number of successive years with comparatively abundant rains, and there is nothing at this time to indicate that history, in this respect, will not repeat itself with a return to another temporary period, not now predictable, when much heavier rains will again be the order of the day.

However, there is one feature of our present-day agriculture in the areas where rainfall is normally small, such as the Northwest, that has served to intensify the damaging effects of these severe droughts recurring at long-time intervals. In the present case severe dust storms have greatly aggravated the situation and the frequency and intensity of these unquestionably are due, very largely, to the comparatively large amount of land put under cultivation in recent years as compared with that in previous droughty periods. The greater the surface of loose, pulverized soil exposed to the wind, the more frequent and intense will be the dust storms and the more damaging the droughts. The answer to this feature of the drought question is, of course, more natural vegetation, more lands maintained in grass, with not too close grazing, and fewer cultivated fields. In this way, and this only, can man do aught to prevent or mitigate the effects of these inevitably recurring droughts.

The amount of damage by drought to the several staple agricultural crops depends not only on lack of moisture, but also the season in which the drought happens to occur. Most crops have a critical period of growth during which they are affected by the weather more than at any other stage of development. Thus, pastures, hay crops and the small grains, such as oats, rye, barley and wheat—especially oats and spring wheat—require favorable weather in spring and early summer, while corn is most affected in the midsummer season during and just following the tasselling and silking stage. Most droughts develop in summer and, consequently, corn is more frequently affected than the small grains.

The 1934 drought developed early, and hay, pastures and small grains are the principal crops affected so far. In the drought area, oats and spring wheat have been severely damaged; pastures are the poorest ever known, and the hay crop will be extremely short, regardless of future weather. Also winter wheat has deteriorated steadily, and the season is now too late for help in the southern part of the wheat belt; harvest has begun already as far north as southeastern Kansas. Corn still has a chance for a good crop if rain comes soon. The first week of June brought very helpful moisture to parts of the northwestern Corn Belt, but much late-seeded grain in other sections still lies dormant in dust at the time of this writing, June 8. This must germinate soon to mature grain before danger from frost next fall.

J. B. Kincer,
Chief, Climate and Crop Weather Division, U.S. Weather Bureau

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CHILD DEVELOPMENT FROM THE STANDPOINT OF GENETICS

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I

THE development of a child begins with a fertilized egg. This is the common view: but actually the beginnings were laid millions of years ago. Unless we approach the problem of development from this standpoint it is comparatively meaningless.

The egg at the moment of fertilization is a minute sphere (Fig. 1), about ⅛ of a millimeter (1–200th of an inch) in diameter. It shows a rather dense body of food (yolk) granules. It contains a large sphere—the nucleus (Fig. 2). There is doubtless some water present, as in other eggs, possibly about 50 per cent. of the total weight. All the cell body outside the nucleus is called cell protoplasm or cytoplasm.

The nucleus is a fluid-filled sphere in which float threads (perhaps a foamwork), in which lie minute organic particles that come together from time to time to form elongated bodies that are called chromosomes. In the child there are in each cell twenty-four pairs of these chromosomes. In each division of the cell each of these chromosomes splits (Fig. 3) into two identically similar chromosomes, of which one goes to one of the daughter cells and the other goes to the other. It is by this means that each cell, certainly at the beginning, receives a full complement of chromosomes.

Development begins by division of the fertilized egg and nucleus into two cells; these divide again, making four; these divide again, making eight, and so on. If the derived cells were each to divide into two repeatedly for as many as forty-five generations there would be produced more than the twenty-six trillion cells which are believed to make up the human body. However, this possibility is actually not realized. Some of the descendant cells slow up very greatly their division; others may go on to many more cell generations.

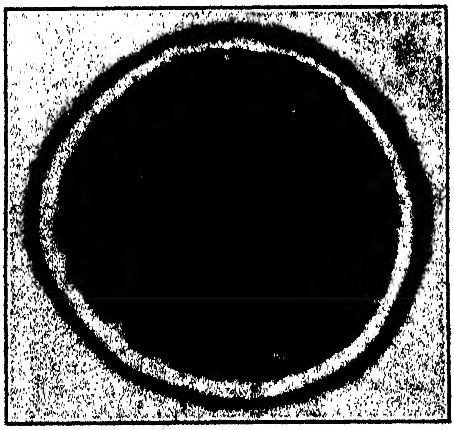

FIG. 1. A HUMAN EGG
FOCUSED JUST BENEATH THE SURFACE SHOWING THE YELLOW YOLK GRANULES ABOUT IN FOCUS AND THE MOSAIC OF WHITE YOLK SPHERES (W. H. LEWIS, 1931).

But not all growth takes place by cell division. A second no less important process is expansion by imbibition of water. After a spherical mass of cells has been produced, a hollow sphere arises of which the wall is made up of these cells (Fig. 4). The hollow sphere contains water which has passed from the medium in which the cell floats through the wall into the center of the sphere. Thereafter, and progressively more and more, the embryo consists of membranes and cell masses which are separated from each other by a large volume of water. Of the young embryo 96 to 98 per cent. may be water. This separation of the different membranes and cell masses gives room for them to fold, and the fluid provides a medium in which the migrating cells of the embryo can travel from place to place inside to the embryonic body (Fig. 5).

A third process in development now becomes more prominent. The cells become different in the act of forming diverse organs and tissues. This process is called *differentiation*. Very early, through a rapid multiplication of cells in one area of the egg, one can locate the point at which the future fetus is to develop rapidly (Fig. 6), and first to appear is the longitudinal axis of the future child. This line, which we may see upon the dense cell area, is the line of its spine. Along this line, cells roll from the outer membrane into the interior to form a long *pocket*, and eventually a long *tube*. This is the beginning of the food canal (Fig. 7). Immediately following the formation of the food

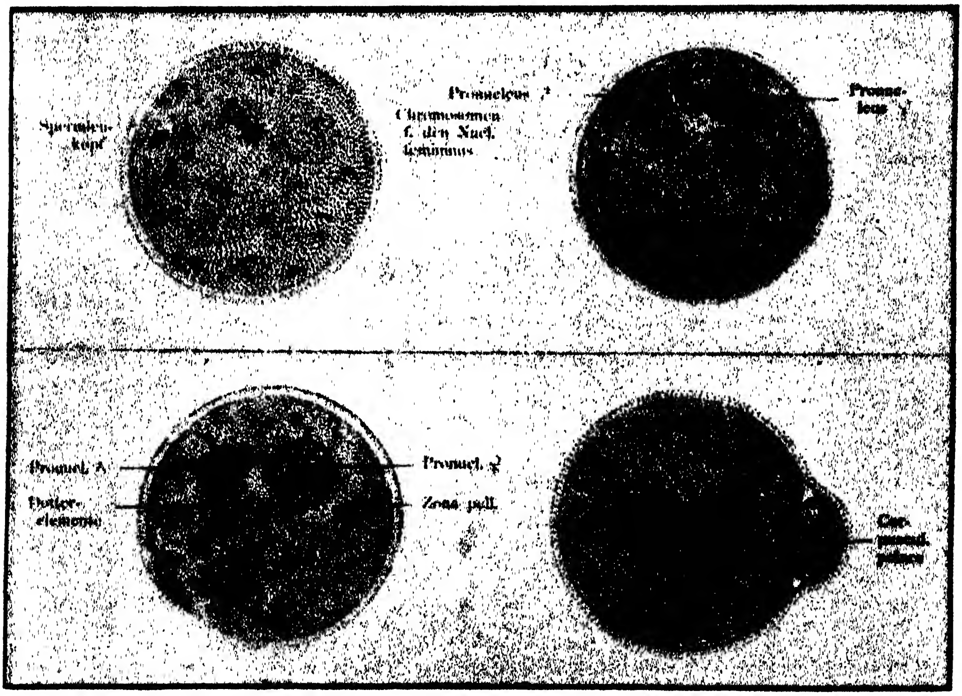

FIG. 2. MOUSE EGG

UPPER LEFT, SPERM HEAD AND FEMALE PRONUCLEI; UPPER RIGHT, MALE AND FEMALE PRONUCLEI; LOWER LEFT, MALE AND FEMALE PRONUCLEI FURTHER DEVELOPED; LOWER RIGHT, MALE AND FEMALE PRONUCLEI COMING TOGETHER, CHROMOSOMES FORMED, POLAR BODIES EXTRUDED (KOLLMANN, 1907).

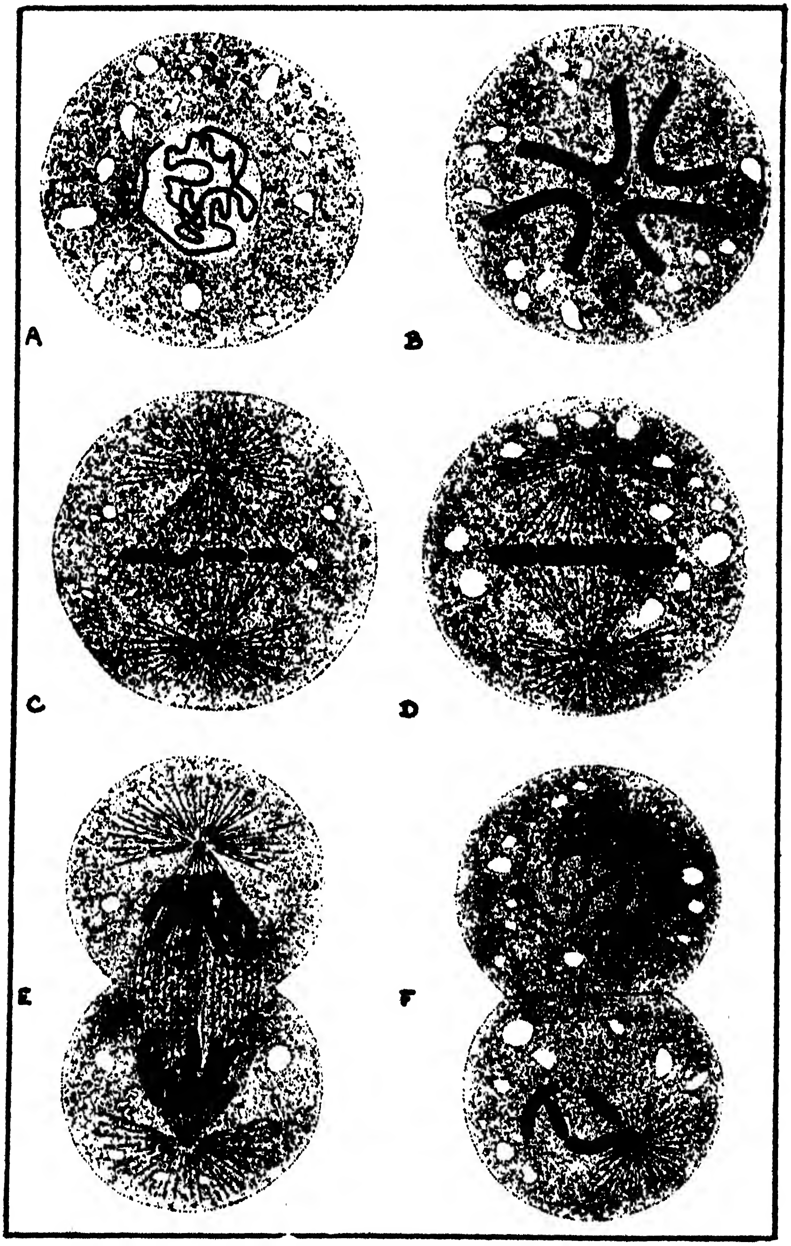

FIG. 3. SHOWING CHANGES

THROUGH WHICH THE CHROMOSOMES OF ASCARIS, A PARASITIC THREAD WORM, PASS WHEN CELL DIVISION TAKES PLACE. DRAWINGS OF ACTUAL SPECIMENS CUT IN THIN SECTIONS. A, EARLY STAGE, CHROMATIN THREAD SLIGHTLY CONDENSED; B, CHROMATIN THREAD HAS FORMED INTO CHROMOSOMES WHICH ARE ARRANGED ACROSS THE MIDDLE OF THE SPINDLE; C, SAME AS PRECEDING, VIEWED FROM THE SIDE OF THE SPINDLE, WITH CHROMOSOMES NOT COMPLETELY IN THE SECTION; D, CHROMOSOMES SPLIT LENGTHWISE; E, CHROMOSOME HALVES MOVING APART, CELL BODY BEGINNING TO DIVIDE; F, DIVISION OF CELL BODY COMPLETE, CHROMOSOMES IN CELL AT TOP BEING RECONSTRUCTED INTO A NUCLEUS (A. FRANKLIN SHULL).

canal there is established the beginning of the spinal axis, and on top of that the beginning of the brain and spinal cord.

Along this axis, multiplication of cells takes place most rapidly at one end, which we soon recognize as the head end (Fig. 8). In it appears the large brain. On each side, the large eyes, nasal pit and mouth are beginning to make their appearance. Behind the head is a long region which represents the embryonic neck. On each side is a series of transverse furrows. These correspond in position to the gill-slits of the embryo fishes. The grooves never become real slits. They do not permit the water to pass by the bars, as in fishes. But these bars play an essential rôle, nevertheless, because from them are budded the thyroid gland and the tonsils.

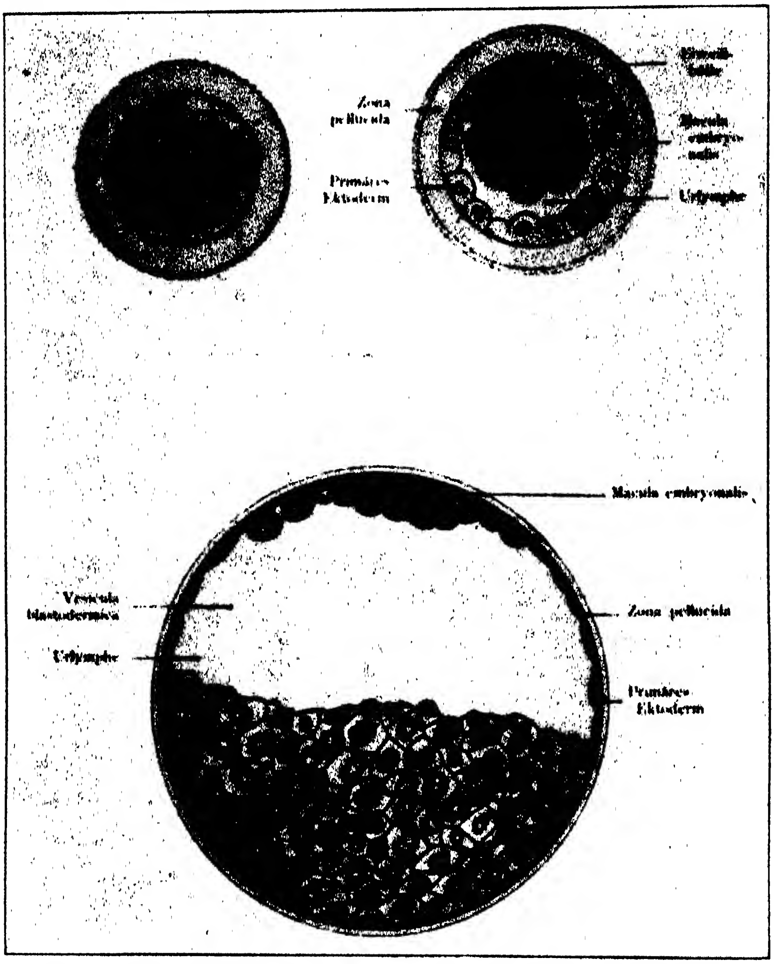

FIG. 4. MAMMALIAN EGGS IN EARLY DEVELOPMENT

UPPER LEFT, BAT EGG IN STAGE OF FOUR CLEAVAGE SPHERES; UPPER RIGHT, EGG OF RABBIT, FORMATION OF BLASTODERM, OR EMBRYO PROPER. LOWER RABBIT IMBIBED WATER DIVIDES THE BLASTODERM ABOVE, FROM THE TROPHOBLAST BELOW (KOLLMANN, 1907).

From the last of the bars arises the hyoid bone of man, which supports the tongue, and out of one of the potential gill-slits arises the Eustachian tube

which passes from the throat by the ear capsule and would open to the exterior of the outer ear were it not for the tympanic membrane that prevents. In these gill-bars are blood vessels which, being no longer required for aquatic respiration, as in fishes, take on another function and go to the lungs instead of the gills. Others supply the brain with nourishment. As soon as these organs are formed, the grooves on the neck flatten out, for, since gills are not required, they have no further function.

Behind the neck the trunk (Fig. 9) is seen as a tubular body, from near the center of which there passes out a cord through which the nutritive fluids pass from mother to child and the waste products are returned from the child to the mother. Already in this trunk we may see the rings or segments of which the body is composed, which correspond in position to the series of ribs attached to the different trunk vertebrae. Finally, behind the trunk, there appears a small

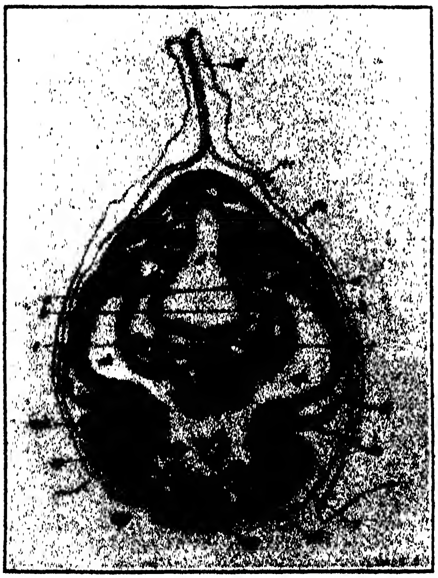

FIG. 5. CROSS SECTIONS OF EMBRYO OF THE TUNICATE SALPA

SHOWING THE RÔLE OF SPACES AND FOLDINGS OF MEMBRANE AND MIGRATORY CELLS IN DEVELOPMENT.

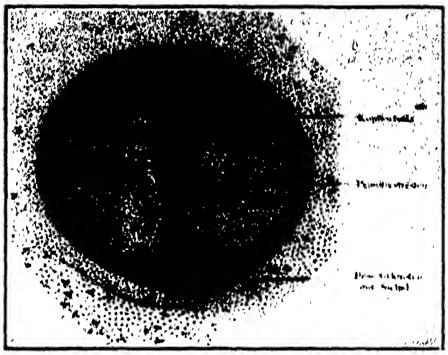

FIG. 6. EMBRYO OF THE DOG

SHOWING EMBRYONIC SHIELD WITH THE AXES OF THE FUTURE EMBRYO IN THE MIDDLE LINE AND THE THICKENING ABOVE TO FORM THE HEAD. THE FURROW WILL FORM THE NEURO TUBE. THE CELLS FROM THE MUSCLES AND HEART ARISE AND ARE BEGINNING TO FORM (KOLLMANN, 1907).

elongated appendage which carries the spine (or its forerunner) nearly to its tip. This represents the tail of fishes and of the lower vertebrates.

The next stage shows that great changes have taken place. The head has become enormously enlarged and from the swollen trunk there arises on each side a pair of flat buds, the beginnings of the four appendages. On each appendage there arise three main segments. On the furthermost segment five lobes form, each one of which eventually represents a finger or toe. The tail gradually becomes resorbed (Fig. 10), as in birds, guinea pigs and apes, until nothing remains of it except a small appendage at the end of the spinal column.

Meanwhile the internal organs are differentiating. From the primitive gut arise lungs, liver, pancreas and other organs. Independently arise the urogenital organs. The skin becomes differentiated. The mouth lining forms tongue and teeth; the skin forms glands, nails and hair. The internal skeleton and muscles become even more complex and mature, and the head and the appendages become mobile. Usually soon

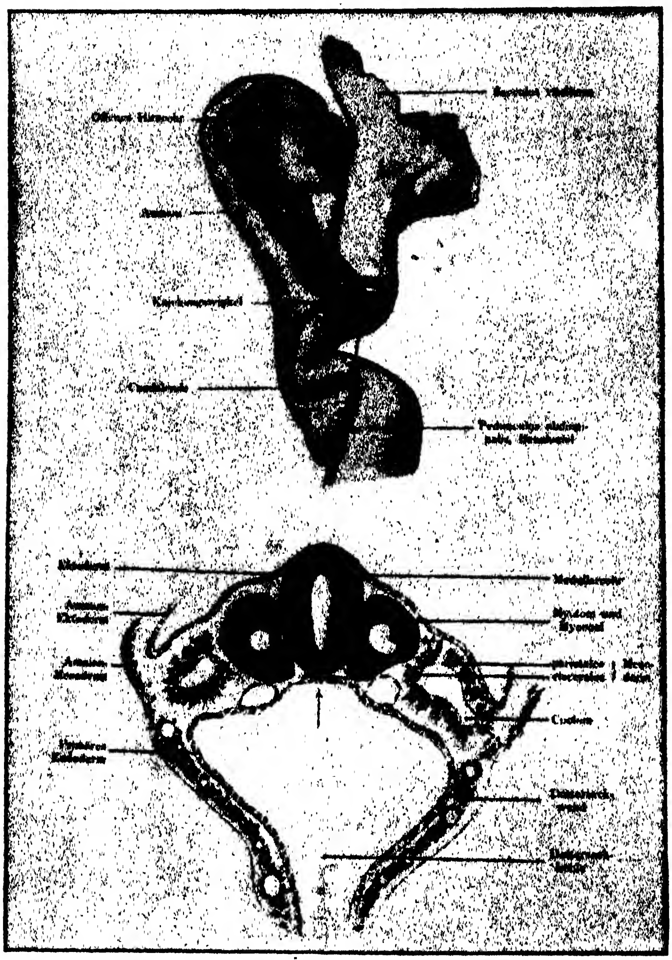

FIG. 7. HUMAN EMBRYO

ABOVE, THE EMBRYO ALREADY SHOWS THE ENLARGED HEAD, HAS A TEMPORARY KINK IN THE BACK. BELOW, CROSS SECTION OF HUMAN EMBRYO AT THE SAME STAGE, SHOWING ABOVE THE NERVE CORD, BELOW THE DEPRESSION IN WHICH THE SPINAL COLUMN WILL ARISE, ON EACH SIDE THE BEGINNINGS OF THE MUSCLE MASSES; AT THE BOTTOM THE FOOD CANAL. (KOLLMANN, 1907).

after birth dark pigment appears; the hair becomes brown or red; the iris, at first blue, may develop a brown coat. The child's mental life develops hand in hand with its nervous system.

To recapitulate: The minute egg forms a germinal disk. Along its axis a fish-like embryo arises; soon this gains the large head and brain and the two pairs of lateral appendages characteristic of the human child. Specialization of parts is completed.

II

Now that we have followed the developing child through the intrauterine period, we return to a consideration of the factors that are operating to produce a child. It is obvious that the form changes which the child experiences are chiefly determined by factors inside the developing organism. It is hardly necessary to say that appropriate external conditions are required; that nutriment must be provided.

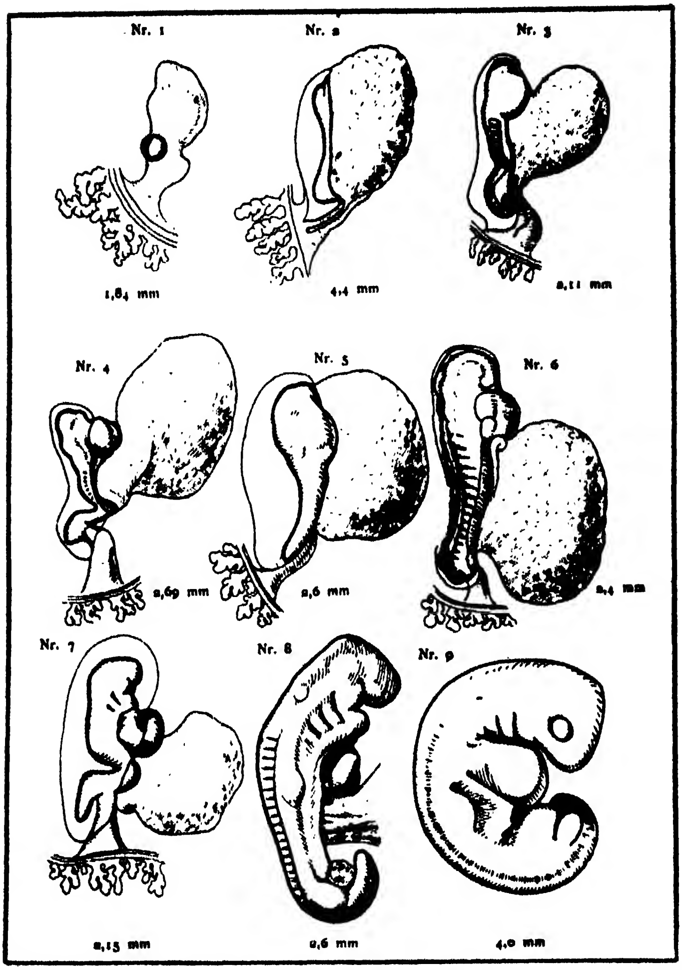

FIG. 8. SUMMARY OF THE EARLY DEVELOPMENTAL STAGES OF THE HUMAN EMBRYO

1, THE EGG IS ATTACHED TO THE MATERNAL TISSUES; 2, THE EMBRYONIC SHIELD IS ELONGATING; 3, MUSCLE MASSES BEGIN TO SHOW AS A SERIES OF COMPRESSED SPHERES ON EACH SIDE; 4, STAGE WITH TEMPORARY KINK; 5, THE KINK IS STRAIGHTENED OUT, THE HEAD IS ENLARGED; 6, SEGMENTATION OF THE TRUNK APPEARS; 7, 8, 9, THE EMBRYO WITH GILL-SLITS AND THE BEGINNINGS OF THE FORMATION OF APPENDAGES.

These are indeed obvious. But given the necessary conditions for development, even including a considerable range of variation in those conditions, the human embryo will proceed along its path to produce a child.

What do we know of these internal facts which direct this development? Philosophers from the time of Aristotle have realized that there must be agents inside of the egg and developing embryo which are directing its course, and these have for three quarters of a century been known as some sort of "genes." It is, however, only during the present century that the philosopher's units have become identified with objects that can be experimented with and whose work can be intimately followed.

Without going into all the evidence that the genes that lie in the chromosomes are largely responsible for direct-

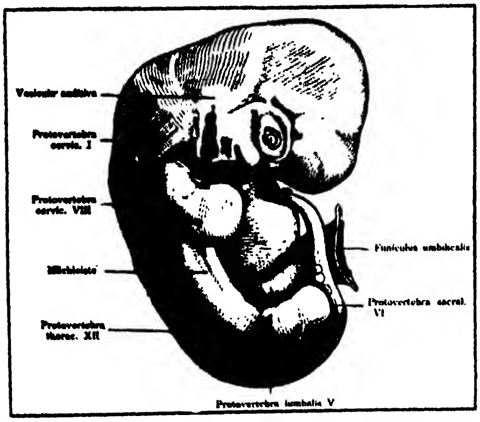

FIG. 9. THE STAGE SHOWING THE BEGINNINGS OF THE VERTEBRAL COLUMN AND THE LONG TAIL (KOLLMANN, 1907).

ing development, I call your attention to some figures by the late Dr. John Belling, which show, perhaps in more or less diagrammatic form, the genes or group of genelets as they lie at the center of a row of spheres, strung along threads (Fig. 11). These collectively constitute the essential part of the chromosomes. These genes are probably large molecules of complicated structure, with a molecular weight of 50,000 more or less, the molecular weight of hydrogen being 1.

They probably are enzymes. Enzymes, I may remind you, are organic chemical substances that belong to the group of catalysts. And catalysts have the remarkable property of accelerating

FIG. 10. DIAGRAMMATIC REPRESENTATION OF THE TIP OF COCCYX IN RELATION TO THE LEVEL OF THE BUTTOCKS. HUMAN FETUS OF TEN WEEKS ON THE LEFT, HUMAN NEWBORN ON THE RIGHT (A. H. SCHULTZ).

chemical processes without themselves being changed or used up in these processes. Enzymes then may be said to be activators of chemical reactions in living cells. Every person who bakes bread makes use of the enzymes of yeast to accelerate the reactions in flour. All fermentation as of cider or wine is due to enzymes.

The genes have each, apparently, the unique property of divisibility into two molecule-groups, like the one from which they are derived. This process is capable of indefinite repetition by which, in the course of time, the descendants of any one gene may become incalculably numerous. The genes in the nucleus are ordinarily two of a kind—paired (one element of each pair having come from the sperm, the other from the egg). The number of kinds of these genes in an individual child is very great, probably thousands. The different gene-pairs play each a different but essential rôle in the cell.

That the genes have different specific rôles to play as directors of development, as well as certain general ones, has been demonstrated, especially by the study of the vinegar fly, Drosophila. Here, some genes are responsible, among other things, for coloration in the eye, others for the form of wings, others for the determination of sex, and so on. In man, no such analysis has been possible as in the vinegar fly. This is partly because the human generation is thirty years, while that of the vinegar fly is less than 30 days; partly because there are twenty-four pairs of chromosomes in man and only four in the fly.

Accepting, as demonstrated, the theory that the genes are the directors of development, the great problem before geneticists to-day is, how do they do their work? To this question we turn our attention. Although the end result is complex the means by which the genes do their work may be relatively simple. Examples follow:

Cell division: It has been shown by Hammett that this can be accelerated by the sulfhydryl group (–SH), and this group is frequently found in the protein molecule. If there are genes that promote cell division, it is probable that they activate some sulfur compounds, as a first step in the process.

Imbibition of water: Many colloids (*i.e.,* non-crystalline substances, like white of egg), such as are found in embryonic cells, are lyophilic (dilute-solution lovers) and may imbibe great quantities of water with change of acidity. Body spaces and probably most membrane *foldings* are produced in this way. One face of a membrane swells over a limited area, and that face becomes convex toward the cavity into which it folds.

Differentiation: Soon after development begins the cells come to have dissimilar contents and form. Special chemical changes are taking place in each. Eventually, special tissues—muscle, nerve, cartilage and others—arise. It has long been known that some of the changes are due to enzymes in the cells. For example, to form the black pigment that is found in hair and iris, and the skin of Negroes, there is present the enzyme called *tyrosinase.* This promotes the oxidation of wide-spread *tyrosin,* which then becomes black. In the absence of tyrosinase in the cells, albinism results. By genetic analysis albinism is due to the change of a single gene and is thus definitely inherited.

Again, it is known that fibrin of the blood is formed in the presence of an enzyme *thrombase* which hydrolyzes (or subtracts water from) fibrinogen. If this enzyme is not found, fibrinogen is absent in the blood in sufficient quantity to permit it to clot. Persons whose blood fails to clot are hæmophiliacs, or bleeders, like the late Tsarovitch of Russia. And genetic analysis shows that this condition is due to a change in a gene that is located in the sex chromosome.

In many plants with highly colored flowers the color is due to an oxidizing enzyme, called *anthocyan,* which acts upon a plant sugar (glucoside) to make red, blue and violet pigment. The brilliant colors of our flowers, our foliage plants and autumn landscapes (Gortner) we owe to these anthocyanins.

These are examples merely to show the great effects resulting from specific gene-enzymes. The ultramicroscopic gene is able to perform such large results by virtue of the catalytic quality of enzymes. These enzymes, indeed, have

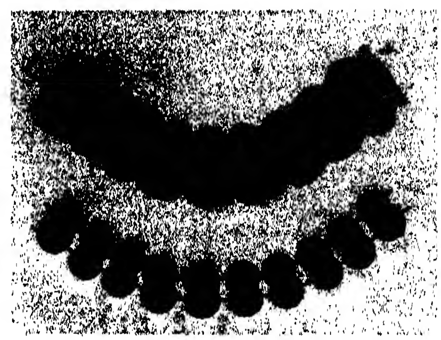

FIG. 11. UPPER, DOUBLE ROW OF CHROMOMERES

IN THE POLLEN MOTHER-CELLS OF ALLIUM (THE ONION FAMILY) AS SEEN UNDER THE MICROSCOPE, GREATLY ENLARGED. THE CHROMOMERES HAVE BEEN SQUEEZED FLAT SHOWING THAT THERE IS AN EXTREMELY MINUTE GENE IN EACH. LOWER, A DRAWING REPRESENTING THE ABOVE DOUBLE STRING OF DEEPLY STRAINED CHROMOMERES BEFORE DESTAINING AND SQUEEZING FLAT.

extraordinary properties, as just indicated. Their action is intense, markedly specific and intimately dependent upon environmental conditions of temperature, acidity, etc. As an example of catalytic action of an enzyme: A peroxidase may activate 1,000 times its weight of H_2O_2 (hydrogen peroxide) per second at 20° C. (Haldane).

Examples of the rôle of enzymes in development might be multiplied indefinitely. We are brought to the conclu-

FIG. 12. FLEXED TAIL MOUSE
MIDDLE FIGURE SHOWS SHORTENING OF THE TAIL AND TENDENCY TO FORM A SPIRAL AT ITS BASE (H. R. HUNT).

sion that enzyme action is an important key to differentiation.

What is known about the source of enzymes? Until now, all known enzymes have been produced in and by the living organism. While some have been recovered from the secretions of organisms, such as digestive juices and milk, mostly they are obtained from the interior of cells and there is good evidence that they control most intracellular reactions.

How do they get into the cell? If, as seems probable, genes are enzymes, then we may say that there has been a continuity of these enzymes from remote time. May we conclude that the genes are the sole source of cell-enzymes? It is indeed nearly certain that in fertilization of the egg the minute sperm brings only genes into the egg—*i.e.*, nothing but enzymes. Since the contribution of sperm and egg to the course of development of the child is the same, we may conclude that the genes of the egg and only the genes are enzymes.

But the egg, unlike the sperm, contains much material besides the genes. If this material is not enzymes it must be that upon which the enzymes act—the so-called substrate (*e.g.*, in breadmaking the flour is the substrate upon which the yeast enzyme acts). For it must be recalled that the genes do not directly constitute the material of the body, but accelerate certain processes of molecular change in the rest of the cell body by which energy is released and the cell body is increased and enabled to produce its specific formed substances, such as are seen in connective tissues, cartilage, bone and certain body fluids.

The cytoplasm affords the building material for growth and differentiation; the genes supervise this growth and differentiation by accelerating the cytoplasmic reactions.

There has been among biologists of this country a sort of division into two groups. One group maintains that the genes are really the builders of the new organism, nourished in some way by the foodstuffs of the cytoplasm. The other group maintains that the egg cytoplasm is immensely important. It holds that the parts of the future embryo are foreshadowed in the distribution of materials in the cytoplasm of the egg.

This controversy seems unnecessary. The genes can do nothing without the cytoplasmic contents to activate. The cytoplasmic chemical processes would be relatively inert without activation by the enzymes. The division of opinion here is as futile as that concerning the relative importance of heredity and environment. Of course, the organism is absolutely dependent on the environ-

ment for its survival; also what the environment does depends upon the nature of the stuff upon which it acts.

It appears that the full complement of the enzymes is brought into the egg at the moment of fertilization. The enzymes are distributed to all the cells of the developing body by the doubling of the chromosomes and their genes at every cell division.

Very early, as we have seen, the cells of the developing embryo begin to undergo *differentiation.* How can the same full equipment of genes in each cell function so differently? To this question Weismann gave his answer: The different cells do not contain the same active genes. There must be a regularly proceeding segregation of the genes in ever smaller groups until finally there remains in each cell only one kind of gene, namely, that which controls or determines the character of that cell. It is highly improbable, Weismann says, that all genes are carried into all stages of ontogenesis.

On the other hand, a careful comparison of the cells of different tissues of the adult body leads to the conclusion that, in general, these cells have the same chromosomes as the fertilized egg, from which they were all derived. However, similarity of chromosomes does not imply identity of their constituent genes; for genes may change without altering the form of the chromosomes.

It is urged that the wide-spread capacity of regeneration of lost parts in various vertebrate species (of which, more anon) proves that somatic cells must contain a full equipment of genes. Indeed, a piece of the leaf of certain plants is able to function like an egg. But this is not adequate proof that all somatic cells contain the same genes, for in all parts of the body there are two kinds of cells, which have long been recognized: First, the relatively unspecialized cells, which probably have a more or less complete set of genes, and which are inactive until called forth by injury; secondly, the active cells which are specialized (or differentiated). It is probable that such specialized cells can not regenerate the whole organism or any considerable part of it.

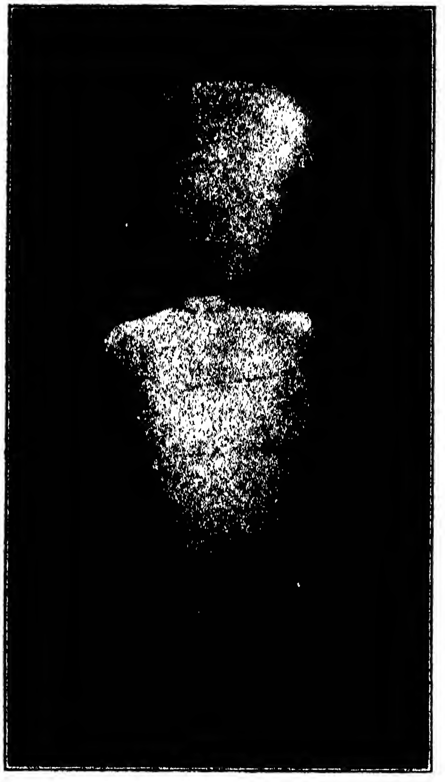

FIG. 13. HUMAN EMBRYO
AT HALF TERM, SHOWING SLIGHT DEVELOPMENT OF PELVIS AND LEGS (KOLLMANN, 1907).

If then somatic cells in general possess the same chromosomal complex, what is probably the nature of the change in the chromosomes that is responsible for differentiation?

This problem appears less difficult if we consider again how the enzymes work. The work that the enzymes do depends upon the nature of the substrate. Now, under the influence of the enzymes of the genes that substrate is constantly changing. Hence the same genes can not do the same work in dif-

FIG. 14. PHOTOGRAPH OF A BABY AT ABOUT ONE MONTH AFTER BIRTH, SHOWING THE SLIGHT DEVELOPMENT OF THE GLUTEAL MASSES, OR BUTTOCKS.

ferent parts of the body or even in the same part of the body at different times.

We must recall that the action of any particular enzyme is highly specific. Thus, *zymase* (an enzyme from yeast) ferments d-glucose, and is quite inactive with l-glucose. The two glucoses have the same structure except for a different position in the molecule of certain atom-groups. Consequently, for long periods during development, a particular enzyme may have no work to do because the nature of the substrate is such that that particular enzyme has before it no chemical reaction which it is able to accelerate.

To make this clearer, we may consider a series of changes in the cell induced by enzymes splitting up. We may assume that at a certain stage enzyme Ea will cause the hydrolysis of the substrate molecule Sa; and this molecule splits up, into Sb and Sc. Enzyme Ea can not split (hydrolyze) molecules Sb and Sc, but some other enzymes Eb and Ec are able to do so and thus produce new cell products. So in succeeding cell generations.

If, following cell division, the cytoplasms of two daughter cells are unlike (as often occurs) then, though the genes be the same in both daughter cells, the reactions occurring in the cells under the influence of these enzymes will be quite different—and cell differentiation will show itself. Such a differentiation once started will tend to become exaggerated in later cell generations and, in time, the various parts of the developing organism will become very different. Thus, each moment of development sets the stage for the next phase, and time and place of action of the genes are automatically determined.[1]

Adopting the point of view thus outlined I think you will agree with me that the enzymes are extraordinarily interesting and important molecular groups. The enzymes are universally distributed among animals and plants. Even such lowly organized beings as bacteria and yeast show already a rich variety of highly effective enzymes. No enzyme has ever been artificially synthesized. When such synthesis is accomplished a step, if only a short one, will have been taken toward the manufacture, in the laboratory, of living matter from nonliving.

But there are other factors to be rec-

[1] A sentence in Wright (1934, p. 32) indicates that he has seen this possibility.

ognized in ontogeny than *kinds* of enzymes. There are the factors of degree and velocity of action. Many traits that differentiate races are of a quantitative order. For example, the newborn Negro child has a cream-colored skin. It is only under the influence of daylight (even very diffuse) that it becomes dark. Many a South European child who is white at birth becomes very dark-skinned when subjected to the ultra-violet rays of the sun. The Negro child simply reacts more quickly and fully to sunlight than the European. We have reason to think that it has more of the tyrosin in its cells, to be turned into black pigment.

European children at birth have blue eyes. In South Europeans, under the influence of daylight, pigment is formed in the iris and the eye becomes brown. The age at which full color is attained varies in different families; in some cases the eye remains light brown, hazel or even blue. The different grades of eye color are merely quantitatively diverse.

Sex would seem to be a sharply marked qualitative character. But the work of the Berlin geneticist, Goldschmidt, indicates that in the gipsy-moth there is a male-determining gene and also a female-determining gene, and that these genes differ in strength in different races. The union of a weak female gene with a strong male gene will produce intersexes among the female progeny. The union of a strong female with a weak male gene will produce normal males in the first generation, but some male intersexes in later generations. The sex actually achieved in the developing organism depends upon the relative strength of the male and female determiners. Thus, there are times when, as it were, one active enzyme struggles against another to secure a place for its products in the development of the body.

We have seen that the same set of genes in each cell may well react very differently because the substrates upon which they act are unlike in different cells. On the other hand, there is some evidence that chromosomal and even gene changes may indeed occur in the cells of the body in the course of the development of the body.

Certain spots, or areas, on the eye or on other parts of the surface of the fly Drosophila are due to irregularities in the *chromosomal complex* that have been induced by x-rays acting on body cells during development. Owing to the occurrence of these mutations first in later stages of development only a small area of the body is affected. Similar results have been found without using x-rays.

In corn grains, in the petals of the larkspur and in variegated plants in general, a definite pattern may arise naturally. It has been demonstrated that this pattern is due to mutations occurring in the genes of somatic cells at a definite time and place.

FIG. 15. PHOTOGRAPH OF CHIMPANZEE SHOWING SLIGHT DEVELOPMENT OF THE BUTTOCKS (A. H. SCHULTZ).

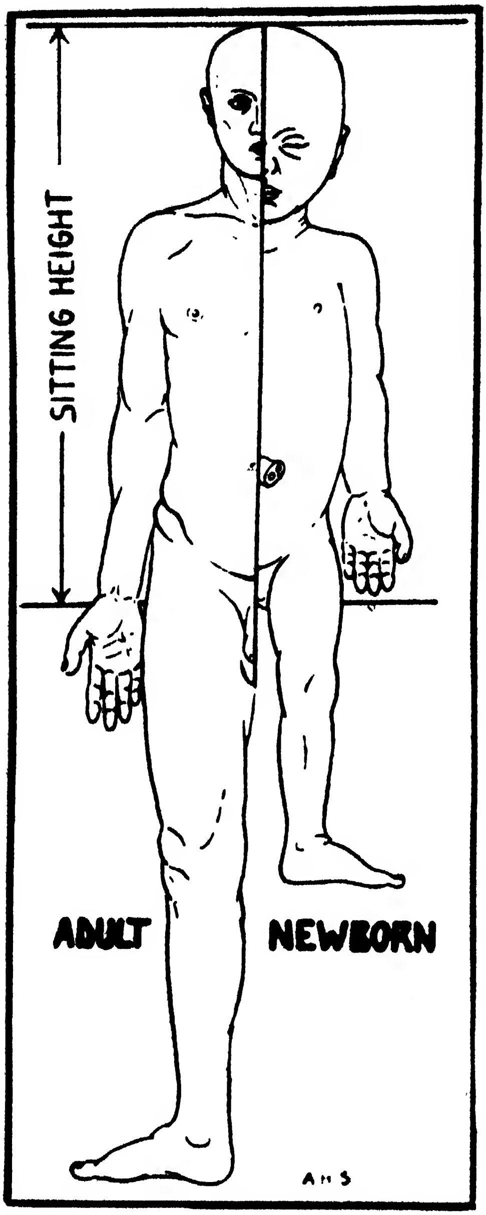

FIG. 16. ADULT AND NEW-BORN HUMANS
DIAGRAMMATIC COMPARISON BETWEEN THE EXACT BODY PROPORTIONS OF EACH, BOTH REDUCED TO THE SAME SITTING HEIGHT. IT IS TO BE NOTED THAT WHILE THE LEG HAS DOUBLED IN LENGTH THE ARM HAS INCREASED ONLY ABOUT ONE-THIRD. THE ARM OF THE NEW-BORN IS PRECOCIOUSLY LONG. (A. H. SCHULTZ).

Thus we see that not only does the substrate of the cytoplasm change under the action of the genes, but the genes may change, perhaps in reaction to the substrate, perhaps under the influence of radiations.

Other classes of differentiating agents that can not be directly due to gene action are harder to understand. For example, in the formation of the eye an optic cup rises up from the primitive brain and touches the embryonic skin. Where it touches the embryonic skin this skin turns down as a pocket, which eventually produced the lens. This reaction will take place even when embryonic skin that was destined to produce the lens is replaced by skin from the belly engrafted on the side of the head in place of the normal skin. The optic cup induces the lens to form even from this foreign skin. Many reactions of this type have been found in the developing embryo.

Even more striking evidence of an organizing action of cell on cell has been found by H. V. Wilson in sponges, in which the cells are rather loosely associated. The cells of a living sponge may be forced through bolting cloth into normal sea water in a receptacle. Soon after the loose cells have settled to the bottom they move toward each other and after some hours they are grouped into a normal sponge structure much as existed before the rough handling. These facts, combined with those of the displaced parts of the skin of the frog embryo which participate in normal development in a foreign location, suggest the presence of certain organizing properties in the developing embryo for which we have as yet no simple explanation.

The foregoing phenomena recall the facts of regeneration. It has long been known that many animals will regenerate lost appendages. When a flatworm

or earthworm is cut in two each piece will regenerate, roughly, what has been lost, so as to reconstruct a functional organism. A great tree may be badly mutilated in a storm, but 10 years later the symmetry of form that belongs to its particular species will be nearly restored. Given the chance and *within limits*, an organic form that has been mutilated will be restored.

responsive to the stimulus of other cells or organs.

Thus, there appear very early in the developing embryo a number of loose migratory cells, resembling the white blood cells. These traverse the cavities of the body, come together to form strands which make eventually the blood vessels. They crowd together below the spinal axis and here develop into a large

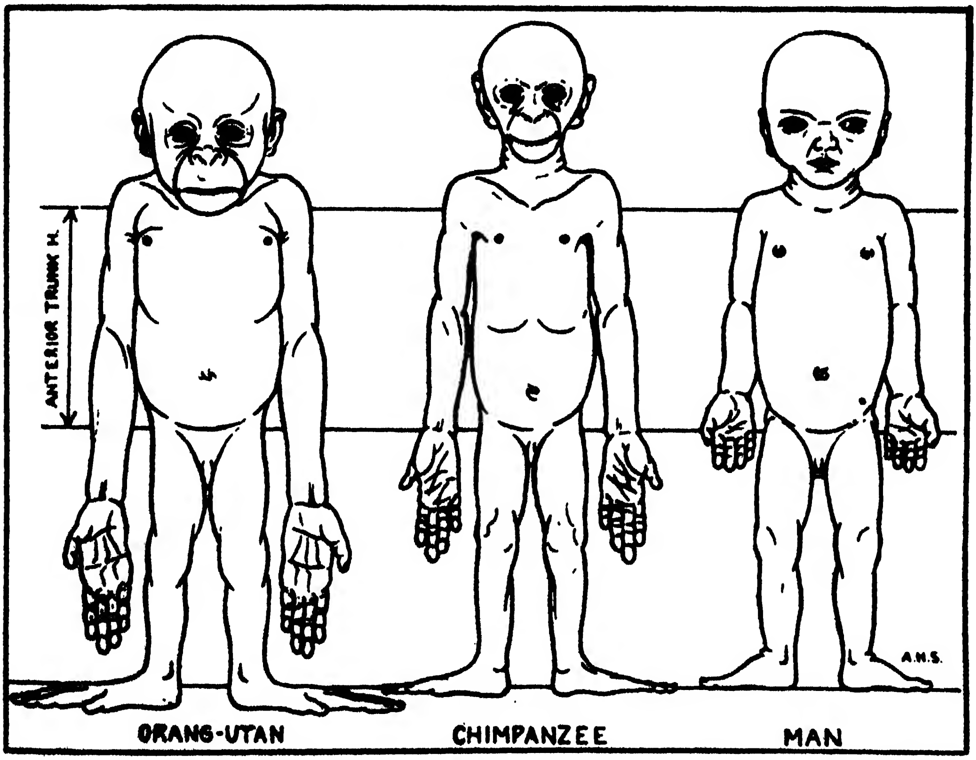

FIG. 17. DIAGRAMMATIC REPRESENTATION OF THE EXACT BODY PROPORTIONS OF NEW-BORN ORANG, CHIMPANZEE AND MAN, ALL REDUCED TO THE SAME ANTERIOR TRUNK HEIGHT. NOTE THE DIFFERENT LENGTHS OF THE LIMBS (A. H. SCHULTZ).

As stated, we know little about the forces that hold the developing organism to its specific form; and restore that form when mutilated. We do know that there is polarity in many elongated organisms and that commonly the head end grows faster than the tail end. Obviously there are other such forces.

At all stages of development the cells of the organism show themselves highly

tube out of which the heart is eventually formed. These primitive vascular threads find their way into the limb buds to supply the growing limb with blood and if (as is perfectly possible) a limb bud is removed from one part of the skin and grafted upon another, some blood threads will find their way to the bud in the new position and penetrate into it.

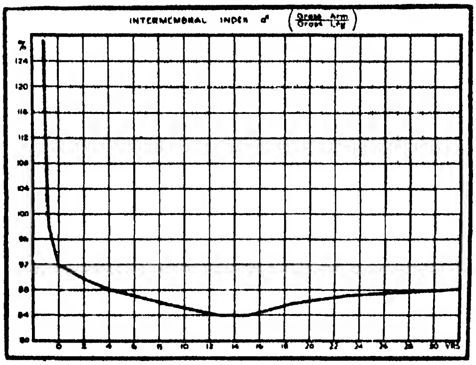

FIG. 18. CURVE SHOWING THE INTERMEMBRAL INDEX IN THE MALE

FOR DIFFERENT AGES FROM BEFORE BIRTH TO 32 YEARS. THAT IS, THE TOTAL ARM LENGTH : TOTAL LEG LENGTH. THE LENGTH OF THE ARM (THAT OF THE LEG BEING 100) IS REPRESENTED BY THE ORDINATES NOTED BY THE SCALE ON THE LEFT.

Again, from the spinal nerve cord there grow out nerves which pass between membranes of the body and make their way to all the developing organs. These pass to the limb buds to innervate the muscles which are to arise there. If an appendage be removed from its normal position and placed somewhere else, a nerve, though not necessarily the one which would have innervated it in its original place, will find its way to the bud in the new place and function there.

What can we say concerning these organ-reactions from the standpoint of genetics? It seems probable that the genes produce substances which exert something of an attraction upon the adjacent organs so as to cause the moving down of the cup of the eye lens, the aggregation of cells to form the blood vessels, movement of the vascular threads toward the muscle masses, the movement of the nerves toward the appendages. We do not know anything definite about the substances which serve as such

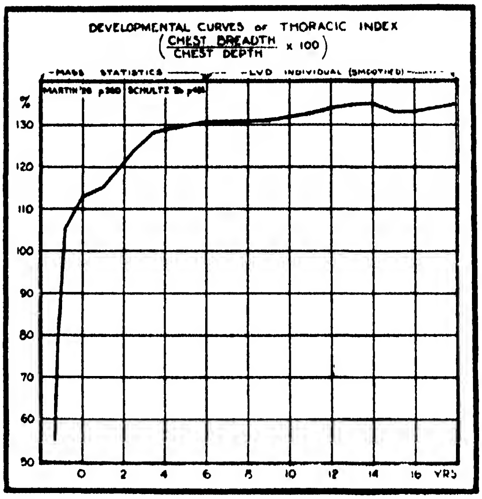

FIG. 19. CURVE OF DEVELOPMENT OF THE THORACIC INDEX

OR THE BREADTH OF THE CHEST; THAT OF THE DEPTH BEING TAKEN AS 100. THE CURVE SHOWS THE VARYING INDEX FROM BEFORE BIRTH TO 18 YEARS OF AGE. BASED ON MARTIN AND SCHULTZ AND NEW DATA.

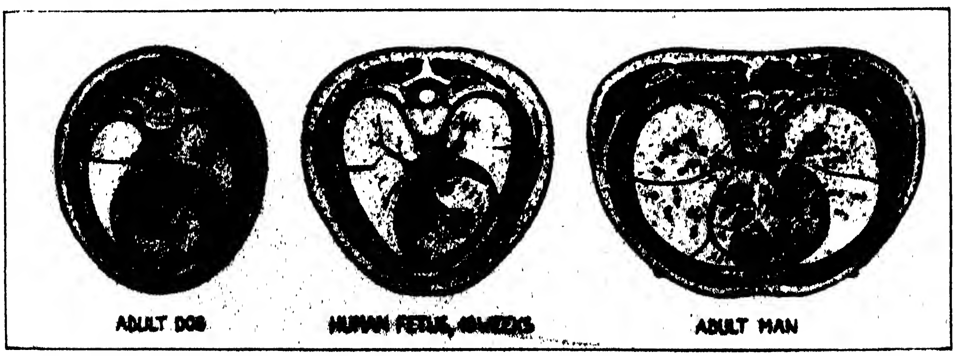

FIG. 20. CROSS SECTION OF THE CHEST OF AN ADULT QUADRUPED, A HUMAN FETUS AND ADULT MAN

SHOWING THE PROPORTIONS BETWEEN TRANSVERSE AND SAGITTAL DIAMETERS. (A. H. SCHULTZ).

gression. We infer that in later life the movement of the white blood cells (phagocytes) toward bacteria are determined by certain substances given off by the bacteria into the medium. It is apparently thus that the white blood cells come in contact with bacteria and devour them. This control of movement of one part by other parts is sometimes called *chemotaxis* (or movement toward or from a chemical agent).

Indeed, we take too narrow a view if we fail to realize that cells are capable of acting upon others and being acted upon; of responding to stimuli.

Hitherto we have considered effects that can be referred to simultaneously acting causes. The action of the gene may, however, be far removed from the visible trait for which it is really initially responsible. This principle may be illustrated by the case of the Kinky-tailed mouse (Fig. 12). This abnormality appears in various degrees. Are we to think of a gene for each?

The study of the earliest stages of this defect shows that the Kinky-tail is the end result of a long series of stages, beginning with a gene defect in the embryo showing at the time the embryonic axis was being laid down. Thus the earliest alternations of development were relatively simple; though severe, not fatal. Subsequent development was accompanied by an attempt of the developing organism to smooth out, or adjust itself to, the defect; so that the final form appears quite trivial, though strikingly hereditary. But it has had a long and varied developmental history.

Again, there is reason for believing that genes, instead of acting directly, may influence development indirectly by means of the activity of the endocrine glands which they have built up. These glands, such as thyroid, pituitary gland at base of skull, and gonads (or sex glands) may then take up the work of finishing off the organism. If the thyroid functions inadequately a dwarf cretin results; if the anterior pituitary and surrounding tissue are deficient a fat child with imperfectly formed genitalia develops, or if the pituitary is overactive the child develops into a giant. The entire series of sex-differentiating characters, including female beauty and male strength and vigor, is derived through the gonads. The endocrine glands are intermediate links of the chain that reaches from egg to adult man.

By such a chain of causes we can understand also how athletic prowess may be inherited; not only a general prowess, but excellence in a specific kind of athletics. What the gene does is not to produce a great runner or jumper, but it influences the length of the femur, or of the lower leg. Apparently, a long lower leg and relatively short femur would favor jumping (even as we see in the kangaroo), while a long femur and short lower leg fits a person for rapid running (even as we see in the gazelle). The developing boy who finds himself genetically provided with long thighs finds that he can run successfully and this gives him so much pleasure that he is apt to enter into competitive sports which involve such running. Because length of thigh is inherited we have families of great runners.

In summarizing the facts of differentiation presented we are amazed at the complexity and variety of processes involved. The genes act directly upon the cell substrate to build up the stuff of which the body is composed. Because the genes or the substrate are different in each child (apart from certain kinds of twins) the adult body is different from that of other children. These genes may differ in speed of interaction in different parts of the body causing differential velocity of growth and differentiation. The genes in body cells may locally mutate in regular fashion so as to produce a new pattern.

Besides the direct action of gene on

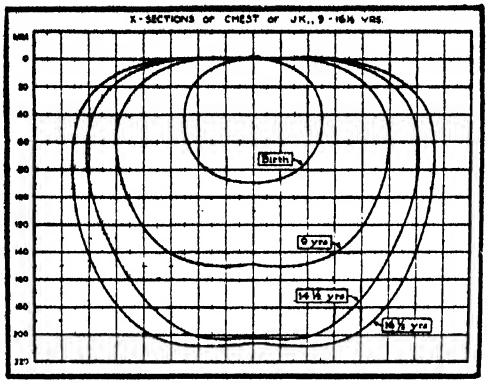

FIG. 21. CROSS SECTION OF THE CHEST OF J. K.

AT 9, 14½ AND 16 YEARS, AND FOR COMPARISON THAT OF THE NEW-BORN, SHOWING CHANGES IN RELATIVE LENGTH OF THE TRANSVERSE AND SAGITTAL DIAMETERS.

substrate we have the phenomenon of organization of the part or the whole body, by which isolated pieces of the embryo go through their destined course under new conditions, though they may force adjacent parts to cooperate with them in a (for them) strange and new course of development. This organizing force leads many mutilated parts to be regenerated, may even cause the separated cells to come together to restore a disrupted being. Throughout the entire developing organism one part is acting upon and securing response from other parts. One could almost compare the organism to an ant colony in respect to the cooperation between part and part. It seems possible that this organizing property inheres largely in the body as a whole, rather than its cells and genes.

Finally, there are many links in the chain between the genes in the egg and the fully developed adult characteristic. The embryo builds up organs for the adult that help complete its development and, as endocrine glands, ensure its constant adjustment to a changing environment.

III

In tracing the development of the child from the egg we have seen that it passes through a series of stages which have apparently little meaning for the grown human and which remind us of stages that are found in the development of the lower vertebrates. For example, I have referred already to the stage of elongated neck with its gill-bars, so similar to that of the stage of the development of the fish. It is easy to see in detail that the human embryo passes through many stages that are characteristic of the young of other species and that may even persist into the adult stage of those other species, though disappearing in the adult stage in man.

For example, a child before birth (Fig. 13) and for some weeks thereafter (Fig. 14) has the great gluteal masses (or buttocks) undeveloped, and on this account can not walk. This stage is that of the chimpanzee (Fig. 15), which can not walk well either.

Again, the relatively long arms and short legs of the human fetus (Fig. 16) are very similar to the early formed long arms of the chimpanzee fetus, which persist in the adult chimpanzee, though the arms become relatively short in the adult human (Fig. 17).

Indeed, the child at birth is far from having completed its development. It goes on showing changes which had been anticipated in intrauterine life until eventually the proportions of the adult are acquired and growth gradually slows down at, or before, the end of the second decade. I will give a few examples.

The change in proportions of arm and leg is brought out in the graph of Fig. 18, in which time (age) in years is marked along the base and the size of the index: arm length/leg length is indicated by the length of the verticals—leg length being taken as 100.

One sees that in the embryo at the third month the arm is one quarter longer than the leg; at birth the two are nearly equal in length, that thereafter the legs grow relatively faster and faster, until, in the girl at about twelve

and the boy at about fourteen years, the arms are about four fifths as long as the leg. After that the legs nearly stop growing and the arms keep on for a little while longer.

Another example—The chest of the child at birth (Fig. 19) is very nearly a cylinder with approximately equal axes. If one thinks of the dorso-ventral axis as 100, then at birth the transverse axis is about 110 (Fig. 20) but increases rapidly to about 125. After that it falls behind, while the dorso-ventral axis increases, but eventually this axis stops growing and the transverse axis continues its increasing breadth. Thus, there is in the development of the child a rhythm in growth, producing changes in proportions.

How do we account for these changes? First, it appears that the cylindrical chest of the human fetus is a generalized form that is found in the fetuses of lower Primates and, indeed, in the adult monkeys. While in some low mammals, like the dog, the dorso-ventral axis (Fig. 20) becomes in the adult the greater, in adult man it is the transverse axis that comes to dominate. The changes that the index of the axes of the thorax undergoes during prenatal life and subsequently to 17 years is shown in Fig. 21 (one and the same boy). The chest at first has nearly equal axes, gains great breadth by 9 years, gets deeper at adolescence and broadens slightly in later life.

This resemblance of certain stages of development of the child to later stages, and even adult conditions, in the lower vertebrates was the thing which led Von Baer to the generalization that in recapitulations of ontogeny the child passes through steps that lie along the lines on which man is supposed to have evolved.

It is obvious that the child does not generally develop the forms which are found in the *adults* of the lower vertebrates. It is, however, true that the lower vertebrates and the child pass through similar stages in early development, and that at a certain point the line of development of the human child diverges from that of the line taken by some of the lower forms, so that the adult conditions of the two become very different, as, for example, in the transitory embryonic gill-bars.

We may say, in general, that the early developmental stages of the vertebrates show many organs in common, though these organs may be only temporary in their appearance in the higher forms. They represent, as it were, the scaffolding necessary to the erection of the building, but something that is of no further use, once the building is completed. Accordingly, when the building is finished the scaffolding is removed.

The similarity in the development of the human fetus and the young of other Primates and other mammals and vertebrates is, however, clearly one of the strongest arguments for the conclusion that these are all related, and it is only in the later stages of development that they have become different from each other. The development of a child can take place only along a narrow path, and for some distance that path is a

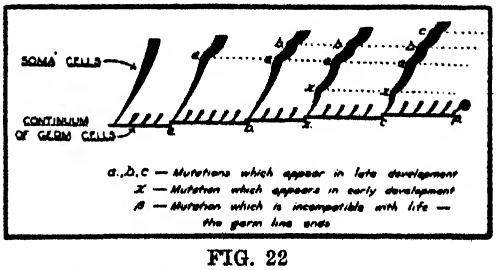

FIG. 22

DIAGRAM SHOWING AT THE BASE THE CONTINUUM OF GERM CELLS THAT PASSES THROUGH THE AGES; ALSO THE SOMAS THAT ARISE FROM THEM (ONLY FIVE REPRESENTED IN EXTENDED FORM). ILLUSTRATES THE INHERITANCE AND PILING UP OF INHERITANCES OF MUTATIONS IN THE INDIVIDUAL SOMA. FOR SIMPLIFICATION, THE ILLUSTRATION IS DRAWN FROM A PARTHENOGENETIC SPECIES, LIKE DAPHNIA; SO IT IS NOT COMPLICATED BY SEXUAL REPRODUCTION.

well-worn one that has been trod by its ancestors and which is still being trod by many related mammals.

What is now the mechanism by means of which these new characters and new proportions enter into the individual development? These characters depend largely upon changes in the genes of the germinal substance, which changes are called "mutations." The mutations are alterations in the substance of the genes or they may be changes in the arrangements of these genes in the chromosomal complex.

Whatever they are, these mutations which ordinarily first appear in the germ plasm show themselves by alterations in the form of the individual that arises from that germ plasm and they are reproduced in the subsequent generation, because the subsequent generation arises from that modified germinal plasm. The relation of the germ plasm and the change in the adult may be visualized in a diagram (Fig. 22) in which I show a series of mutations in the germ protoplasm A, B and C. These modifications persist in that germ plasm and the modifications which they induce recur in successive generations that arise from the modified germ plasm. Most of the mutations that survive affect last-formed organs. Mutations of early stages would probably cause death.

Summary

In conclusion, the development of the human child, like that of the young of other mammals, is a series of changes in size, proportions and complexity of parts that is clearly directed by internal factors—genes.

These genes do their work by relatively simple processes that direct cell division, growth of the body as a whole, and of its parts. They determine the fate of the tissues either directly or through the hormone-producing endocrine glands that they create. The successive situations or stages reached at any moment afford the situation to which the appropriate gene or genes respond. Between the genes in the cell nucleus and the cell environment is constant action and interaction as stage after stage is built up.

Besides the genes there is an organizing agency which controls form of the body as a whole. Now, the course of development is not arbitrary because it is not new. It proceeds along a necessary path—a path worn by its early vertebrate and early mammalian ancestors. In so doing it recapitulates, in part, the ontogenesis of those early ancestors and reveals to us in an only partly obscured light what those ancestral ontogenies looked like.

The development of the child is not finished at birth and, indeed, for twenty years after birth it goes on changing, guided ever by the traditions of former remote ontogenies. However, step by step the growing child incorporates the more recent mutations at the appropriate time and place.

Genetics is the study of the way a changing body reacts in the presence of a complex system of responsive genes to build up in well-established fashion an organization capable of surviving in its environment and thus of nursing and transmitting further the potentially immortal germ plasm that it carries.

CLIMATE AND HEALTH

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MAN is a creature of his environment. So often has this been said that we have come to believe in this all-inclusive statement as one which requires no further definition. As a matter of fact there are many different types of environment, such as physical, social and intellectual (to mention only a few), as there are different types of human beings in these respects, though the development of our civilization has shown that increasing importance and significance should be attached to the effects of combinations of environments, particularly when we attempt to evaluate any one as to its influence upon the complex human organism. With regard to climate and its effect upon physical man and his state of health, which is the subject we wish to discuss here, we have learned with what difficulty it is possible to establish controls in the purely scientific aspects of the subject and we realize that, as yet, much of the advance in this field must have its genesis in the realm of philosophy before the laboratory of environment can test the principles and hypotheses which are evolved.

The subject of climate and health is almost as old as man himself. Since the early records of time reference has been made to conditions of climate and disease. In ancient days it was common to associate the plagues of disease with climatic changes thought to have been wrought by the Deity as a form of punishment for a wicked world. Philosophers early postulated the miasmatic theory of the origin of many diseases, and it is only comparatively recent that scientific demonstration of the germ theory effectually destroyed this doctrine of a less enlightened period. We have then in the subject of climate and health one which reaches back into the dark ages, and even to-day, as we shall see, a scientific approach to this ancient problem is only in its infancy.

A more modern point of view regarding climate and health was initiated early in the seventeenth century with the formation of the East India Company under a charter granted by Queen Elizabeth. The early adventurers in the field of medicine who went to India soon began to think and write concerning the climate and associated health problems. It was inevitable perhaps that climatic contrasts which these men from more temperate climates experienced should have focused their attention upon this problem. And yet only the most general observations came from these early pioneers and we find no scientifically controlled studies in the records. However, their contribution remains a definite one, since they served to emphasize the importance of the subject.

In recent decades the problem of climate and man has been the subject of several notable reviews. Among these may be mentioned such studies as those of the Carnegie Institution of Washington in 1914 on "The Climatic Factor as Illustrated in Arid America"; "Civilization and Climate" by Huntington, first published in 1915; "The Tropical Sunlight" by Freer, 1910; "The Physiological Effects of Tropical Climate" by Sundstroem, 1922; "Climate and Acclimatization" by Castellani, 1929; "Medizinische Klimatologie" by Brochardt, 1930, and many shorter treatises dealing with various phases of the subject, some

of which will be referred to later. At the present time Mills has a monograph in press dealing with climate and health, several chapters of which are available to the writer in manuscript. Still another evidence of the increasing interest in this subject is the recent formation of the International Association for Geographic Pathology, which indicates a recognition of the principle that there exist geographic differences even in the effects of disease.

A few years ago Huxley stated so aptly that "Man's thought and social life are built on his economic life; but this, in its turn, rests on biological foundations. Climate and geology between them decide where the raw materials of human industry are to be found, where manufactures can be established; and climate decides where the main springs of human energy shall be released. Changes of climate cause migrations, and migrations bring about not only wars, but the fertilizing intermingling of ideas necessary for rapid advance in civilization." This author further stated that "Disease and hygiene play as important a part; half of the population of the world is permanently below par on account of animal parasites such as the hookworm and the microscopic malaria germ; and disease may bring about the rise or fall of empires. Nor has selection ever ceased its rigorous activity. To pass from one mode of life to another is not a simple affair for a people; a settled agricultural life demands a very different temperament from hunting, and the hereditary make-up of the race must be altered if a people is to pass successfully from one to the other. . . . The only zones where vegetation is abundant and man can easily flourish are the temperate and the tropical. But the temperate has another advantage. It contains the belt of cyclonic storms—in other words, of rapid and frequent changes of weather. And this type of climate, as Ellsworth Huntington has shown, is the one most stimulating to human energy and achievement." In these few observations of Huxley we have a concept of the problem and some indication as to its deep import. With this brief historical background and introduction to the subject of climate and health, let us proceed to a definition of the terrain and a discussion of our specific problem.

Climate is usually defined as the temperature and meteorological conditions of a country, or as the effects of the sun, atmosphere and earth upon living objects at a given place on the earth's surface. Thus, radiant energy is one of the elements of climaté, as are also humidity, rain, snow, wind, density, electrification and temperature, all of which determine, with other factors, what the atmosphere shall be. These various elements, according to meteorologists, are dependent upon fixed and natural factors. It is because of these many elements of climate, which are dependent upon fixed and natural factors, that so many variables exist in the study of the problem of the effect of climate upon living objects. In the field of physiology of climate Sundstroem apparently recognized these limitations, for he emphasizes the study of problems in this field by "groups" in the tropical belt "as a whole" when, as he states, it will be possible to follow up any promising phase to a point beyond mere "suggestions" with due consideration of the correlations with other body functions, and when, consequently, the whole science of physiology will be placed in the tropical frame.

Climates are usually classified as (1) astronomical, (2) geographical, (3) topographical and (4) physiological. Castellani refers to the classification preferred by Supan, namely, the solar or astronomical basis of division. In this classification we have (a) tropical or

warm climates, extending from the Equator to the mean annual isotherm of 20 degrees C. or 68 degrees F., (b) temperate climates, extending from lands possessing a mean annual isotherm of 20 degrees C. or 68 degrees F. to those which have a temperature of 50 degrees F., and (c) cold climates, lying polewards of the isotherm of 50 degrees F. This is perhaps the simplest classification and one which will serve our purpose as a basis for discussion, though we must not lose sight of the modifications of these divisions which geographical and topographical features bring into the picture, such as continental and oceanic considerations or, by contrast, the variations between mountainous areas and the plains in the topographical scheme. The climate of Baguio, for example, is more invigorating in the Philippines than that of Manila or Culion at sea-level, where the effect is of a relaxing type. Scores of examples of this type in both temperate and tropical climates might be mentioned where often, from the physiological point of view, marked differences exist when altitude compensates in part for latitude. Frequently such variations may be encompassed within the limits of a few miles as the crow flies.

We have seen that man builds and adapts his social existence upon his economic life. It is because of this that we have movement from one place to another and now and then large migrations of people take place almost *en masse* from one part of the world to another. Centers of new population have thrived only where the fundamental necessities of fertile soil and water exist. Given a fertile soil and a supply of good fresh water the factor of health is of next importance, although health can not be dissociated from man's fundamental problem of nutrition. It is therefore because of migrations that we must consider health problems first and so the question of climate and health may be regarded as one which is essentially basic to man and civilization. To understand something regarding the relation of climate and health we must study the effects of the former upon the latter. In a gross fashion it may be possible to state offhand that a given climate may or may not promote good health. The making of such a statement, however, is merely lifting the lid from a large pandora box, the contents of which must then be carefully sorted and examined. It is this sorting which has given trouble, for the contents of the box, corresponding to the elements which make up a given climate, vary not only among themselves in type but also vary in degree and we find ourselves surrounded by a maze of things which do not explain everything as we had hoped when we lifted the lid. If we wish, for example, to test the effect of a drug on a living organism we first select a normal individual for the experiment. Next comes the question of the amount of the drug to be employed. A small dose may produce certain effects, while larger doses may produce more pronounced effects and additional changes as well. Although many of the changes can be measured and accurately charted, we are assuming that in the first instance we have selected a *normal* test organism. Here the first error may enter our experiment. Admitting that our test organism may be as *normal* as any of its species, it does not necessarily follow that the action of the drug on this organism will be the same for the so-called normal member of another species, and further we know that organisms of the same species may vary one from the other in type and degree of response to the same stimulus. And so in the study of the effects of climate on normal man we are handicapped at the outset in two very important ways, namely, the variables of the climatic elements themselves and the multitude

of "combination effects" which they may produce due to individual variation in degree and man himself, the test organism in this particular problem, who notoriously possesses individual characteristics which hereditary factors have, in the beginning at least, determined for him. Fortunately, however, within these limits, certain general effects may be expected to be brought about by extraneous agents in various members of a given species and, to compensate for the differences which nature has provided, we employ a sufficient number of the test organisms in order to compute *an average effect* of our test agent. Care must always be taken, however, to take into account other causal effects which may unintentionally enter the experiment.

Let us at this point briefly mention some of the effects whicn are said to occur in man who has migrated from a temperate climate, which is characterized by unsettled weather with variable changes in temperature, rainfall, moisture, storms, cold and hot waves, floods and droughts, to a tropical climate, which is characterized by being mild, equable, moist, warm, with frequent rainfall and heavy over water and over windward land exposures, with few general storms and with dry and rainy seasons. Leaving aside for the moment certain racial peculiarities (such as the Negro of Africa, who is well adapted to his warm climate, or the Latin and Jewish races, who seem to be less affected by climatic changes) and considering the Anglo-Saxon as our test organism, let us see what general effects we may expect from reported studies, on the average, to take place. The literature would indicate that under such conditions of change in climate there is a tendency for respiration to be slower and for pulmonary capacity to be increased; body temperature is said to rise slightly at first but to return to normal in the individual who acclimatizes readily; some investigators have reported an increase in the pulse rate, while others claim there is a diminution in the rate; differences in blood pressure have been noted, some investigators asserting there is no permanent change, while others claim the systolic pressure may be lowered as much as ten to twelve points and the diastolic pressure in similar proportion; haemoglobin is said by some authors to be decreased in tropical climates, while the red cell counts may remain normal, but there is no agreement regarding this matter; the blood sugar, it has been claimed, is higher in tropical climates, but some investigators have found normal values or even slightly lower readings than normal; the cholesterin of the blood is generally stated to be somewhat lower, the non-protein nitrogen is said to rise during the warmer periods, while the phosphorus content of the blood is said to diminish; growth in stature but not in weight has been suggested; the age of sexual maturity is said to be lowered; hot climates are said to predispose to sterility of women, to menstrual abnormalities, to abortions, post-puerperal hemorrhage and an earlier menopause. There is said to occur a lowered power of digestion and a tendency towards constipation; several reports indicate that there is a lowered basal metabolic rate, but other reports deny this; a depressing effect on the nervous system has been described; urinary secretion is said to be diminished and there is thought to be an increased concentration. In addition to these general observations it may also be mentioned that certain investigators have claimed that the endocrine glands are at first stimulated in tropical climates and later depressed. The adrenal glands particularly are said to be adversely affected. Sexual power is at first stimulated, according to some observers, and later

definitely depressed after prolonged residence in warm climates. There is said to be an increased elasticity of tissues, resulting in a general sluggishness and relaxation.

The warm climates are also said to predispose to various skin diseases, such as fungus infections and to bacterial and parasitical diseases in general, due to the debilitating influences already mentioned, which may tend to lower general body resistance. These are only a few of the vicissitudes about which the average Anglo-Saxon might be concerned, should he contemplate transplanting himself to a tropical climate from a colder environment. But how much of this is factual and really established upon a scientific basis? We venture to state that very few of these observations are as yet firmly established. For several years the writer has been interested in this question, and a thorough study of the literature together with more than casual observation of some of these problems has convinced him that, as yet, few fundamental basic observations or principles have been established in this field of study. However, these various observations are deeply significant. The reports of the many investigators who have worked with these problems contain, without doubt, factual observations upon the particular groups studied by them in the particular climatic environments under which their observations were made. There would seem therefore to undoubtedly exist a distinct realm of study and knowledge in this field of climate and health and one which should be the subject of an aggressive, though conservative, scientific attack.

While contrasts in climatic change, such as movement from temperate climates to tropical climates, must bring about physiological alterations in the human organism, it is also probably true that movements of people from the warm belts to the colder climates also produce definite physiological changes. Whether either of these alterations *per se* so affect the individual as to change his resistance and susceptibility to infectious diseases is not established. There has been much loose thinking about this question. It must be remembered that bacterial and other parasitic agents of disease are disseminated largely by human and other carriers or by actively infected individuals themselves. The movements and interchange of people back and forth across the Tropics of Cancer and of Capricorn must determine largely this question of the dissemination of such diseases and not the changes in climatic environment. It has frequently been stated that respiratory diseases are more prevalent in temperate climates than in tropical areas and the pneumonias are frequently cited as examples. This is only a half truth and a misleading one. Only a few years ago the writer was informed that pneumonia is uncommon in Puerto Rico, but subsequent study of this problem revealed that the pneumonias are not an unusual condition in this island. With the constant interchange of people between Puerto Rico and the United States, particularly with New York City, this is not surprising and, indeed, was to be expected. Furthermore, during the great pandemic of influenza some fifteen years ago the tropics were not spared, particularly those tropical areas where the reservoir of infection potential was raised high enough to initiate an epidemic. It must be kept in mind that migrations of individuals from temperate climates to tropical climates are still at comparatively low levels. Scarlet fever is also considered quite rare in tropical countries, but there is nothing certain, as yet, that there are any climatic influences which prevents the spread of this disease in warm climates and if the

carrier level for the causative agent were to be raised sufficiently high in tropical countries it is possible that this disease would also be prevalent, as it is in colder climates. By the same token we have recently learned that amoebic dysentery, while being a disease most prevalent in tropical countries, is no respecter of climates. When conditions of human congestion and faulty sanitation occurred in Chicago during recent months and the infection was introduced, it was spread to hundreds of people, many of whom are now scattered in different parts of the United States. These things, we believe, are not fundamentally a matter of climate, though climatic factors have no doubt indirectly, at least, influenced the picture.

In Siam we are told that urinary calculi are most prevalent, but that gall stones are uncommon. The question arises whether several factors do not contribute to the high incidence of bladder stones in such countries, such as water intake, concentration of urine, calcium and other salts in the water supply, the squatting posture commonly employed during urination, which tends to leave a residual urine in the bladder or perhaps elements of diet or a vitamin deficiency. The answer to this question is not known as yet, but it will most probably not be found entirely associated with the conditions of climate met with in Siam. Nephritis and diabetes are also less prevalent in tropical countries than in cold climates, though several writers, upon theoretical grounds, have assumed that the former should be quite prevalent in warm climates due to disturbances in water regulation and accompanying retention and concentration of urine. While diabetes occurs in tropical countries, its incidence is much lower than that of temperate climates, though due perhaps to other factors than climate. Rheumatic fever is also less prevalent in tropical climates, as are many other diseases believed now to be of infectious origin, but here again we are dealing with germ diseases and we have seen that other factors operate in their dissemination and climate plays perhaps only a minor rôle.

It is readily seen that many questions have been raised in regard to this question of disease and climate. The tendency has been to lay as much stress as possible upon climatic influences. This is perhaps a hangover from our early concepts of tropical medicine. We quite naturally came to think of tropical diseases as affections which were peculiar to the tropics when, as a matter of fact, only a few of these diseases would be peculiar to tropical environments if given a favorable opportunity to be introduced and spread in temperate zones. To be sure, there are certain diseases spread by insects which will probably always be more prevalent in warm climates, since arthropods tend to thrive best in such climates; but it must not be forgotten that malaria was not unknown in former years in our northern states and yellow fever could exist even to-day fairly far north in the United States, where its mosquito vector is prevalent a few months out of each year.

Climate again is only indirectly involved in the picture. In the survey of tropical diseases, which is now under way in the National Research Council, we have listed over eighty diseases which are usually included among the so-called tropical diseases. It is not the thought of the advisory committee on this study that these diseases are of tropical origin in the sense that they thrive only in tropical climates. Most of these diseases could occur anywhere, and it is because of this possibility that the survey is being made. With a world which is constantly growing closer together through

modern methods of communication and transportation, it is important that we learn as much as possible regarding this large group of diseases which, at present, largely inhabit tropical countries. Unfortunately, but necessarily, this group of diseases must continue to be referred to as tropical diseases, since no better designation is available. But the usual emphasis of climate *per se* as the chief responsible factor in their distribution must be dismissed. Rather should we think of these diseases as a group the incidence of which is highest in tropical countries for various reasons, including a favorable climate, or at least a climate which is not unfavorable, and then let us consider climate in its proper relation to these various health problems and through the scientific method determine where and how it fits into the panoráma. In general, much of what can be said of this question of climate and health in relation to warm climates and temperate climates can also apply to arctic areas, though scarcity of population in these areas at present makes this problem a comparatively minor one.

Let us therefore return again, at this point, to our original premise that the human race builds and adapts social existence upon economic life. We will not, however, forget the biologic fundamentals or the rôles climate and geology must play in this social existence and economic life. Civilization has developed to its greatest heights in temperate climates. In these stimulating zones of definite seasons and climatic changes from day to day great industrial and agricultural developments have taken place. The per capita of wealth has, with few variations up and down during relatively brief periods, steadily increased. Hand in hand with this we have seen the organization of community life supported by community funds through taxation and philanthropy. Of chief importance in this development has been the organization of health programs. Along with modern water supplies these communities have developed modern methods of disposing of sewage and other refuse. Streets and alleys have been paved and trunk lines of paved highways have been developed between villages, towns and cities. Modern methods of illumination are found nearly everywhere. With the increase in wealth better and more commodious homes have been erected as have schoolhouses, community halls, churches, auditoriums and theaters. Health inspection and laws protect food supplies. The school physician and nurse have been recognized as community assets. Health departments and hospitals have developed clinics for the poor, and governments, both state and federal, have established institutions for the mentally sick and for specific diseases, such as tuberculosis. This development is still going on and will probably never fully meet the complete needs of our increasing populations. But already, as a result of these enlightened developments, we can evaluate much of what has happened. Many diseases, formerly common, are now considered rare. A community formerly considered malarious is now free of the disease, and typhoid fever, for example, is practically never seen by medical students in some of our northern institutions during their entire four years of training. A hundred years ago these diseases flourished in various parts of the United States and Europe—now they are not so common, except in certain areas. Modern sanitation, mosquito control, specific immunization, preventive medicine and health education of the individual and community have changed the picture.

Contrast this with conditions in the tropical belt. Here bare existence must be extracted by hand almost entirely from the soil. Wages are usually piti-

fully low and capital is scarce. Industries of our modern civilization are practically unknown. Poverty is the rule rather than the exception. Density of population is becoming an increasing problem. Housing is inadequate and unhygienic and in its type of construction contributes itself to diseases of many types and protects only from the elements of weather. For the most part there is no safe water supply, no sewage disposal, no hydroelectric power and consequently only the poorest of illumination. Educational facilities are the exception rather than the rule. Food is scarce and of limited varieties. There is little or no health inspection. Life is still primitive. Disease is rampant, the life span is short and infant mortality is extremely high. Due to climate, we say? Only indirectly. If the same standards of civilization were prevalent in the tropical belt to operate for the benefit of the untold millions of inhabitants as these high standards operate for the benefit of man in temperate climates, the picture would be vastly different. Evidence of the truth of this statement is easily found in those tropical areas where high standards of living have been introduced, but unfortunately modern civilization, as we know it, has never touched most of the tremendous area of the tropical belt. There lie ahead of us, of course, vast areas for industrial and trade development among these millions of people in tropical climates who need nearly everything which man in temperate climates possesses and considers essential in his everyday life.

With these considerations in mind, are we still to regard the native of warm climates as the victim of his climatic environment? Indirectly, yes, because his climate is generally considered less desirable and other people will not turn to it for permanent abode until their economic life demands it. But aside from these considerations has the tropical climate a direct bearing upon health? For both the native and also for the emigrant we believe this must be answered quite definitely in the affirmative. Given all the benefits of modern civilization we feel there would still exist a hazard to the fullness of health in the warmer climates. Aside from general observations, whether established or unproven as yet, which have already been mentioned, there is direct experimental evidence that certain elements of such a climate are capable of producing profound effects upon living organisms. Sundstroem, for example, has shown that the humid heat of warm climates constitutes a growth-retarding factor for mice and rats under experimental conditions. In mice which were grown in a "tropical room" he demonstrated a temporary growth stimulation, though he states succeeding generations may behave differently, and after a couple of generations with extremely stunted growth a generation was again reared which exhibited a more satisfactory growth. This investigator states that strong light alone was shown to possess a growth-stimulating effect, but when combined with humid heat suppressed the growth below the levels exhibited by the series exposed to only humid heat. Further improvement followed when motion of the hot and humid air was produced with electric fans. Sundstroem believes that any measure which raises the cooling power in a humid and hot environment will at least partly neutralize the growth-retarding effect of the tropical climate. Further experimental observations are recorded by this author on the retardation of the growth of hair on animals kept under tropical conditions, which correlates with observations which have been made upon man. Similar observations were made for the growth of the nails. Pigmentation of the skin in tropical climates is also affected, as

judged by observation on man himself and the application of the experimental method to animals.

There is also experimental evidence accumulating that the endocrine glands are affected in their function by tropical climates. Hart, Mills and Stoland and Kinney have all reported a decreased function of the thyroid gland in animals reared in hot environments. Perhaps the observation concerning a drop in basal metabolism in similar environments by Sundstroem may be related to these experimental observations. Dunn has reported an increased toxicity of insulin when temperatures of the rooms were increased in which the animals were kept. Knipping has described changes in the cellular structure of the hypophysis in swine imported to tropical countries. Steinach and Kammerer have reported proliferation of the interstitial cells of the testes of rats which were reared in a warm environment. McKinley and Rivera reared standard white rats under controlled conditions in tropical sunlight and have described profound effects which were produced in the testes and adrenals of these animals. The intensity of the ultra-violet light of the sun during 131 hours of exposure of these animals was recorded by Hernandez and McKinley.

It will be recalled that Schanz in 1919 studied the effects of definite regions of the spectrum on a variety of plants. This author found that plants grow higher the more the short rays of sunshine are excluded. The greatest height was obtained under red light and the minimum under blue light. Chlorophyll development in certain plants was more rapid under red light and retarded apparently with the shorter rays. Equally of interest is the work of Kammerer, who has reported the development of a functional eye in the blind cave salamander when exposed to light and the report of Sheard who, in 1926, described the growth-promoting effects of radiation from a quartz mercury lamp upon frogs' eggs which persisted for twenty-four hours, was then retarded, and was followed on the third day by abnormalities of development. Likewise, Northrup, in 1925, found that the larval period of *Drosophila* was shortened slightly when exposed to Mazda lamps at intensities around 2,500 metercandles, but were increased at higher intensities. When we come to mammals we find that, according to Frank, children up to two years of age show a sharp rise in the growth curve from April to June, a drop during the summer months, a second rise in September to November and there is a dip in the curve again in December and January. Sundstroem, however, reports that growth of children in Australia does not differ from that of children elsewhere. Borissow found that dogs and rabbits grown in light weighed more than those grown in darkness after a few weeks under these conditions, though Degkwitz has found practically the opposite for puppies. Interesting reviews on radiant energy are to be found in the monographs of Laurens and Luckiesh.

To refer again to our own experiments along this line of investigation in 1929 sixty white, male rats, three weeks old, average weight of forty-four grams, were placed upon Sherman's 13 standard diet. Each animal was placed in a separate wire cage. Half of the animals were raised in a darkened room, while the other thirty rats were placed in the sunshine each day for varying periods of time. This experiment was carried on at the School of Tropical Medicine, in San Juan, Puerto Rico, and was begun late in November of that year. The experiment was continued for eleven weeks and was terminated the end of the first week in January, 1930. Each day the food consumed was weighed and

charted, the animals of both groups being permitted to eat only during the night. Once each week the animals were weighed and the food consumption for the week was calculated and the loss or gain in weight for each animal was recorded. The total of hours of sunshine to which the experimental animals were exposed was tabulated each week. As a rule the animals were exposed to the sunshine in the late morning and early afternoon hours when the greatest intensity of radiant energy, barring certain factors, prevails. The individual cages containing each animal were placed upon a chicken wire netting raised about eighteen inches off the ground, and the cages were so constructed that the animal had no opportunity to seek any shadow for protection against the sun's rays. The total number of hours of exposure to tropical sunlight for the experimental group of animals was 131 over the eleven-week period. At this point it had been planned to test a certain group of these animals for resistance against an infectious agent, controlling these animals with a similar group of the animals which had been raised in a darkened room, but these plans did not materialize. Consequently at the end of the experiment the animals were all weighed, were then killed and the weights of the adrenal glands, the two testes and the spleens were determined.

It will be noted that the control animals at the end of the eleven-week period had an average weight of 156.6 grams; that their average weekly gain in weight exceeded that of the sunlight group by a small margin; that their total gain quite definitely exceeded that of the sunlight group; that their intake of food was nearly 25 per cent. greater than the sunlight group; that their adrenal glands, on the average, were lighter by a small margin than the sunlight group, even though their total body weight was definitely greater; that their testes were nearly twice as heavy as the testes of the sunlight-exposed rats and their spleens were considerably heavier, which might be explained, of course, on increased body weight alone. The sunlight-exposed rats, in addition to being smaller, were not as active or alert as the control group. They had a smaller weekly gain in weight, but also they had a smaller weekly intake in food. However, although the animals were smaller, their adrenal glands were somewhat larger than the control group, but their testes were only half as large as the control animals.

These experimental results, under such well-controlled conditions, led us to believe that there might be in these observations something of decided importance. The marked delay in maturation of the testes and the delayed involution of the adrenal glands in the sunlight-exposed rats indicated that perhaps great intensity of radiant energy over a long enough period might bring about significant physiological changes in a test animal.

The following year we decided to repeat the experiment during the same season of the year in the same environment, but this time we measured the solar intensity each day by the oxalic-acid-uranium acetate method, and in addition we decided to study the effects upon other organs, such as the thyroid and thymus, and to include some female animals in the experiments so that the ovaries might be compared in the two groups.

The second experiment was begun early in October, 1930, and the study extended to the third week in January of 1931. In this experiment there were eighteen rats in the control group and there were 19 animals in the sunlight-exposed group. At the end of the 14th week the average weight of the control animals was 139 grams and that of the

experimental group was 134 grams, or approximately the same. The food intake of both groups was approximately the same, indeed within 0.3 of a gram according to our figures, though the actual difference may have been somewhat larger than this. Again, the average weight of the adrenal glands of the sunlight-exposed group was higher than that of the control group, but no such difference, as in the first experiment, was obtained for the testes. In the second experiment the weights of the testes were nearly the same in both groups of animals. In this experiment the experimental animals were exposed to 136 hours of tropical sunshine, which in actual measurement accounted for the decomposition of 1067.32 mgms of oxalic acid in the presence of the catalyst when exposed to the sun in a quartz cell. This corresponds roughly to about 350 erythema skin doses for the skin of human beings. The few female animals in both groups showed the ovaries of the control group to be slightly heavier than the ovaries of the sunlight-exposed group, but hardly enough to be significant. The data for the thyroid and thymus glands were not significant.

While we feel that such experiments as we have described are not conclusive, still the fact remains that a significant difference does exist, for some reason, in the maturation of the testes, between the two groups of animals in one of these experiments. We feel that the conclusion to be drawn from these experiments is that the variables are too numerous to properly control, and yet it seems quite definite that there are several fundamental questions involved in this work which should be given further study. No doubt the same type of criticism might be offered to several of the observations dealing with the many studies on climate and health, but for the present, at least, it would seem that further progress may best be made with these problems by studying them with the experimental method in animals. That there is much to be learned is indicated by the promising suggestions which have resulted from such investigations so far.

Following Huntington's thesis that human energy is affected by the variability of the weather Mills has been engaged during the past few years in studies attempting to link up climatic features with definite disease processes. The observations by this investigator are suggestive of climatic influences in such conditions as heat stroke, acute nephritis, diabetes mellitus, death rates from pernicious anemia, exophthalmic goiter, Addison's disease and angina pectoris. Mills has stated that human fertility is highest in a given population at a temperature of about 65° F., and that it is reduced during the low temperatures of the northern winter and by mean temperatures above 70° F. In a recent paper he has pointed out certain dangers to southerners in northward migrations due to climatic changes. These are stimulating observations by Mills and they are certainly suggestive. When and if the experimental method may be applied to some of these interesting problems they will no doubt be accepted with greater favor and interest by biologists.

Reed lists some twenty factors in his study of medical geography in the tropics. This author goes so far as to include religion and politics among these and states that "health is a balance obtaining between the life principle as exemplified in man, and the sum total of his environment." He feels that a new era in medical science is taking us rapidly into a field which can be termed medical geography. In this we would certainly agree.

Reed has mentioned one factor, namely, food and diet, which we feel

deserves further comment in relation to the question of climate and health. It would matter little what the climate is if man is without proper food. Food supply is, in turn, directly related to climate, and it is our considered opinion that too often the factor of nutrition is given too little attention while climatic factors are perhaps given too much. Of the two nutrition would seem to be the more important and, without question, this factor, and others as well, may frequently complicate studies designed to determine the effects of climate on the living organism. It is highly important then that the element of nutrition be well controlled and understood in all studies dealing with health.

In conclusion we feel constrained to insist that, despite the present chaotic state of our knowledge in this field of climate and health, there is indeed in this subject a significant realm of thought for future experimentation. A few pioneers have blazed the trail up to this point with inadequate facilities and little support, but many suggestive and interesting lines of attack have been brought to light. Future developments in our civilization will no doubt focus greater attention upon these problems, and the golden reward which awaits man in his social, economic and physical life, following their solution, should further enrich scientific knowledge and all the peoples of the world.

THE DARK GALAXY

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The question is often asked whether among the myriads of shining stars there are not numerous dark bodies or planets as well as smaller pieces of non-luminous material in the vast inter-stellar spaces. Our experience on the earth, as each hour we sweep up only a few meteors as the earth travels thousands of miles in its motion about the sun, would lead us to infer that space as a rule is fairly empty, but our solar region may not be typical.

If there are dark planets connected with other stars, we have no means of finding them. In the thousands of close double stars, the smaller bodies are, so far as we know, always self-luminous, and as a rule they are far more massive than any of the sun's attendants. Small planets revolving about the stars, or even bodies larger than Jupiter, are quite out of our reach. Moreover, so great are the distances between the stars as compared with their diameters that for every luminous body in sight there could be many dark objects of comparable size without our being aware of their presence.

Obscuration Power of Dust

It is only when material between the stars takes the form of small particles like gas or dust that we are likely to detect its presence from the obstruction of light. If a solid body is broken up into similarly shaped pieces each half the diameter of the original, there will be eight new objects each with a quarter of

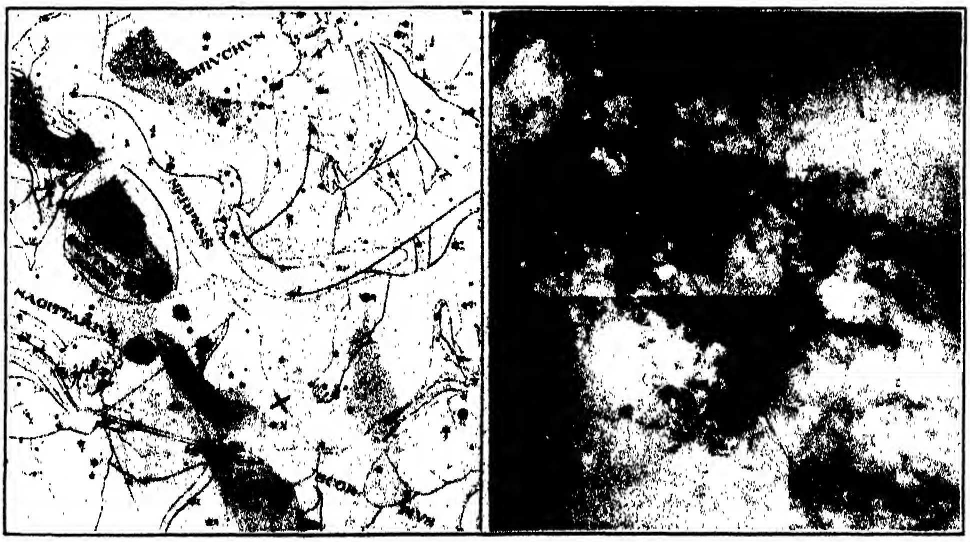

Fig. 1. Left: Star map showing two branches of the Milky Way in the region of the center of the galaxy, which is marked by the cross. Right: Mosaic photograph by Ross, showing star clouds and obscured regions near the center of the galaxy.

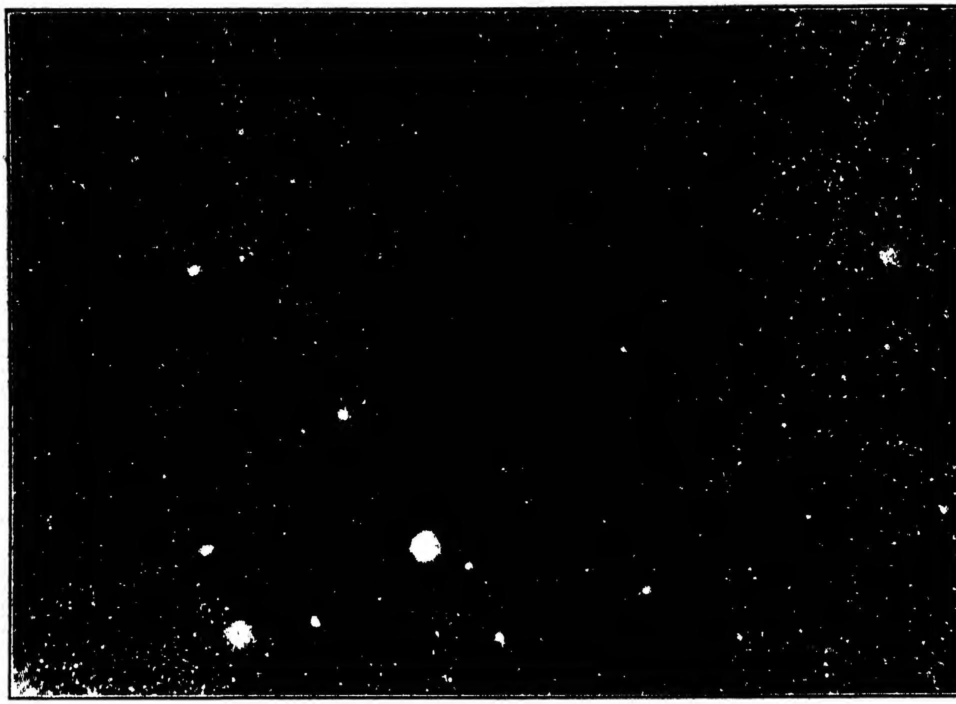

FIG. 2. DARK AREAS IN THE MILKY WAY.

the surface of the first body, but having a total of double the area or occulting power. Similarly, if a star a million miles in diameter were divided into globes each one mile across, the increase in surface would be a million fold. Another division by a million in the linear scale would give particles comparable with coarse sand, and a further division by one hundred would give dust particles of a diameter about 1/600 centimeter. Counting up the factors we have $10^6 \times 10^6 \times 10^2 = 10^{14}$ as the increase of surface area produced by pulverizing a solid body the size of a star down to the consistency of fine dust.

The number of individual stars that can be seen or photographed with present telescopes does not much exceed 10^{10}, so with due allowance for the gaseous state of the hot stars we have the rather striking inference that if a single body like the sun were broken up and distributed around in space in the form of fine dust, the obstructing power of this matter would be greater than that of all the stars in sight. Therefore, if light from certain parts of the sky seems to be obstructed, the screen or curtain which blocks our view is more likely to be a mass of small particles than a clustering of stars.

The simple geometrical consideration of the obstruction of light by different-sized bodies holds only so long as the particles are large compared with the wave-length of light. There is a range from a given limit down to the dimensions of molecules, call it between 10^{-5} and 10^{-8} centimeters, where the action of particles is to scatter in all directions the light which falls upon them, rather than to obstruct or reflect it back toward the source.

The amount of this so-called Rayleigh scattering depends upon the color—strictly, it varies as the inverse fourth power of the wave-length—and it is made evident to us in the blue color of the sky. When we see the sun reddened

FIG. 3. N.G.C. 891. A SPIRAL NEBULA OR GALAXY SEEN EDGEWISE.

near the horizon due to the longer path of the light through the atmosphere, the blue light which has been taken away from our direct perception has contributed to the color of the sky somewhere else. Likewise if between us and a distant star there are a sufficient number of gas or dust particles of the size that produces scattering rather than obstruction, we shall find a certain space reddening of the light coming to us, just as we do for the sun at sunset. In the process of either obstruction or scattering there is what we may call absorption, as the observer receives less light than he would if space were empty.

Evidence of Dark Material

There is strong enough evidence of dark material or dust in our stellar system. In Fig. 1 (left) are shown portions of the Milky Way as it is represented on a star map. The two branches, one of which almost fades out, were formerly attributed to the arrangement of clouds of stars, but it is now universally agreed that the division is due to a widespread obstruction of light in space.

The combined photographs in Fig. 1 (right) give a better idea of this region of the sky than can be had by direct vision on a clear dark night. It must be more than a mere coincidence that the center of our galactic system, determined from positions and motions of many stars, should be just in the general direction where the Milky Way is divided, and where the evidence of dark material is most conspicuous. It may not be true that the rounded bulge of obscuration about the position of the center marks a dark kernel of our system, but at least there is no other region in the sky where the appearance gives such a strong suggestion of a nucleus.

At first glance it is not easy to distinguish between spaces which are between clouds of stars and the real effect of absorption, but any hesitancy that we have in accepting the presence of dark mate-

FIG. 4. THE PHOTOELECTRIC AMPLIFIER ATTACHED TO THE 15-INCH REFRACTOR.

rial is overcome by the appearance of such regions as that in Fig. 2, which is a much larger photograph of the first bright area to the right or west of the center in Fig. 1 (right). The conspicuous S-shaped affair, and smaller attendants, from their very appearance give the impression of complete obscuration. In many places the edges of the black spots are too sharp for it to be plausible that we are looking along holes or vacancies out to where there are no more stars. There is often the complication of stars in the foreground, and we have to do the best we can in conceiving of a simple model of the stellar system when stars and dark stuff are promiscuously intermingled.

We are in much the same position as one bee in a swarm trying to make out some order of arrangement in the neighborhood: there is always the interference of the foreground companions. Our bee would get a better idea of his own swarm by looking completely outside for another swarm. We too can get some hints of our own galaxy by scrutinizing an external nebula as in Fig. 3.

Consider the appearance of the heavens to an observer placed in the median plane of such a system and say two thirds of the distance out from the center to the edge. He would have a band of light or Milky Way extending all around his sky, and in one direction, toward the center, this band could well be divided lengthwise by a dark region. The conception of the nebulæ being systems of stars like our galaxy is now universal, and we may fix the idea by learning the astronomical multiplication table, "A thousand million stars make one galaxy; a thousand million galaxies make one universe."

Since there are many other flattened galaxies which show dark streaks down the middle, the evidence of possible absorbing material in other systems is wide-spread. Thus far, however, we have considered only the obstruction of light that is unaccompanied by scattering. The stars which we barely see through clouds of fine dust ought to be reddened, and we may digress to consider the means which have been developed to detect such a change of color if it exists.

The Photoelectric Amplifier

As supplements to the eye and photographic plate various physical instruments have been developed, among which is the photoelectric cell. This well-known device has been increasingly used in recent years; in fact, it has been well said that the applications of the photoelectric cell are limited only by the imagination of the experimenter. Such cells have been known in the laboratory for half a century, but now we have their everyday use in talking pictures and television, for sorting or shading beans, buttons or cigars, for counting automobiles and pedestrians, for burglar alarms, for stopping or starting anything, even up to the World's Fair, and finally for measuring the Milky Way.

It was the advent of the thermionic vacuum tube as developed for the radio that made possible the use of the extremely minute current which is generated in a photoelectric cell when exposed to faint light. Such a combination of cell and tube for use on a telescope is shown in Fig. 4.

For many years the cells produced by Dr. Jakob Kunz, of the University of Illinois, have been applied to stellar photometry, the measuring instrument for the current being hitherto some form of electrometer. The improved installation with cell and tube, mounted inside a tank from which the air is exhausted, as perfected by Dr. Albert E. Whitford at the Washburn Observatory, is considerably more stable and sensitive than previous forms of the photometer.

An indication of the sensitivity of this so-called photoelectric amplifier is given by some tests made at Madison. The instrument was detached from the telescope and directed to an ordinary candle set up a mile distant across Lake Mendota. With an exposure to this light the amplified photoelectric current caused a deflection of over 150 millimeters on the scale of the galvanometer, which was repeated at will with a probable error of less than 2 per cent. With the incident light reduced some fifty-fold the deflections were about 3 millimeters and the probable error only about 0.2 mm. By actual test the amplifier has thus easily shown the presence of a light equivalent to a candle at seven miles distance, farther than it can be seen by the eye; and the calculated limit of detection was a candle at about 30 miles, neglecting of course the effect of absorption by the air beyond the first mile which was actually observed.

As the window of the photoelectric cell was just one inch in diameter, it is easily verified that the factor of increased power of the amplifier attached to a telescope is given simply by the aperture of the objective in inches.

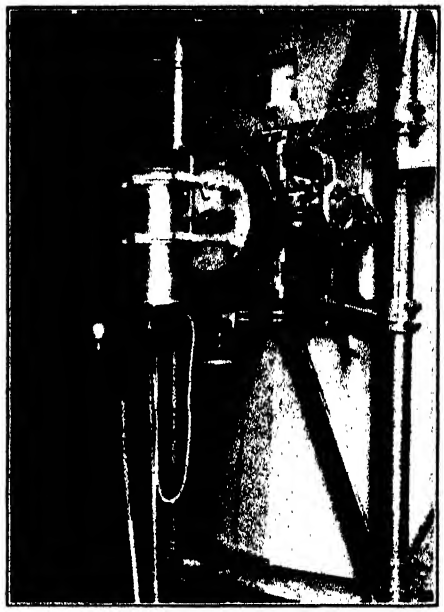

FIG. 5. THE AMPLIFIER AT THE NEWTONIAN FOCUS OF THE 100-INCH REFLECTOR.

Thus the installation on our 15-inch refractor would reach a candle at 450 miles, while with the 100-inch reflector the limit would be extended to 3,000 miles. Experience has shown that this degree of sensitivity can be maintained in practical working conditions for months at a time.

The installation of the amplifier at the upper or Newtonian focus of the 100-inch reflector at Mount Wilson is shown in Fig. 5. For a star or nebula the total light can be determined, and then by insertion of suitable filters the spectral intensities in the blue and yellow regions are compared, giving a measure of the apparent color or the degree of reddening of the object. The operation of the amplifier on the large telescope is a three-man affair, requiring the regular night assistant to point to the selected region of the sky by means of the divided circles, one observer to identify the field, pick up the individual object, make the exposures, etc., and another to read the deflections of the galvanometer, located

solidly at the base of the mounting and connected with the moving end of the telescope by some 120 feet of flexible cable.

Our Galactic System

With this digression as to methods of observation we return to considerations of the galaxy. The present conception of the general Milky Way system or galaxy to which the sun belongs is that of a very flattened watch-shaped system (Fig. 6), with which are connected the outlying globular clusters some 93 in number, but the arrangement of the clusters is nearly spherical in form. Each globular cluster is a system on its own account and comprises thousands of stars (Fig. 9a). Just why our galaxy should consist of the flattened main

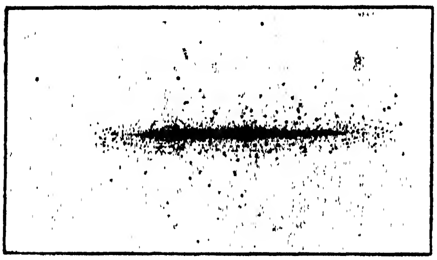

FIG. 6. THE GALAXY, AFTER OORT.
THE SUN IS AT THE CENTER OF THE CIRCLES; THE RADIUS OF THE OUTER CIRCLE IS 8,000 LIGHT YEARS, A THOUSAND TIMES THE DISTANCE FROM THE SUN TO SIRIUS. THE LARGER DOTS REPRESENT GLOBULAR CLUSTERS.

group of stars with the related more dispersed system of globular clusters is not understood, but Hubble has found more than one hundred objects, tentatively identified as globular clusters, in much the same relation with the Andromeda nebula.

The sun is placed at a considerable distance out from the center of the galaxy, at the center of the small circles drawn in Fig. 6. Because of our immersion in the mass of stars the extent of the system is not easy to determine, and is still a matter of discussion among astronomers. We are probably able to see very few individual stars beyond the galactic center; in the median plane it is very doubtful whether our range extends even as far as the nucleus, and the overall dimensions have been inferred from Shapley's determination of the general system of the globular clusters.

Perhaps a fair estimate of the current notions of the diameter of the main part of the galaxy is 80,000 to 100,000 light years, though in the opinion of the present writer this figure is more likely to be reduced than increased. All distances inferred from the apparent brightness of objects of assumed intrinsic luminosity are affected by absorption of light in space, and it is just in the direction of the galactic center and beyond that this absorption is most conspicuous.

If we consider an observer near the sun studying the arrangement of stars at successive steps of increasing distance, as indicated by the concentric circles in Fig. 6, then as the stars become apparently fainter they would be distributed in narrower bands agreeing roughly with the position of the Milky Way. A selection of uniform stars is furnished by the B-stars of the Harvard classification. These objects, sometimes also called Orion stars from their prevalence among the bright stars in the constellation of that name, are among the hottest and brightest known.

Their intrinsic luminosities range from 500 to 1,500 times that of the sun, and hence they may be seen at great distances. Fortunately, also, their spectra are relatively simple, without the complicating effect of many strong dark lines or bands to cause abnormalities of color. At Madison we have recently completed a study of some 700 B-stars, all those brighter than visual magnitude 7.5 which could be reached in the northern sky.

Measures of the colors of these stars were made by Dr. C. M. Huffer and myself with a photoelectric cell attached to the 15-inch refractor. The idea at first

was to compare the colors of B-stars in pairs or small groups, taking one or more objects within an obscured region, and then others not far away where the stars were apparently more numerous. Any scattering of light by small particles in the spaces of the dark region would show up as a reddening of the partially obscured stars. This test was found not to work out so simply, as all the stars in a large region of the sky were likely to be found to be affected. As the work progressed the observers became aware that any strongly reddened B-star was almost certain to be close to the apparent central line of the Milky Way, usually within two or three degrees of the so-called galactic equator.

The results of the color measures of B-stars are charted in Figs. 7 and 8,

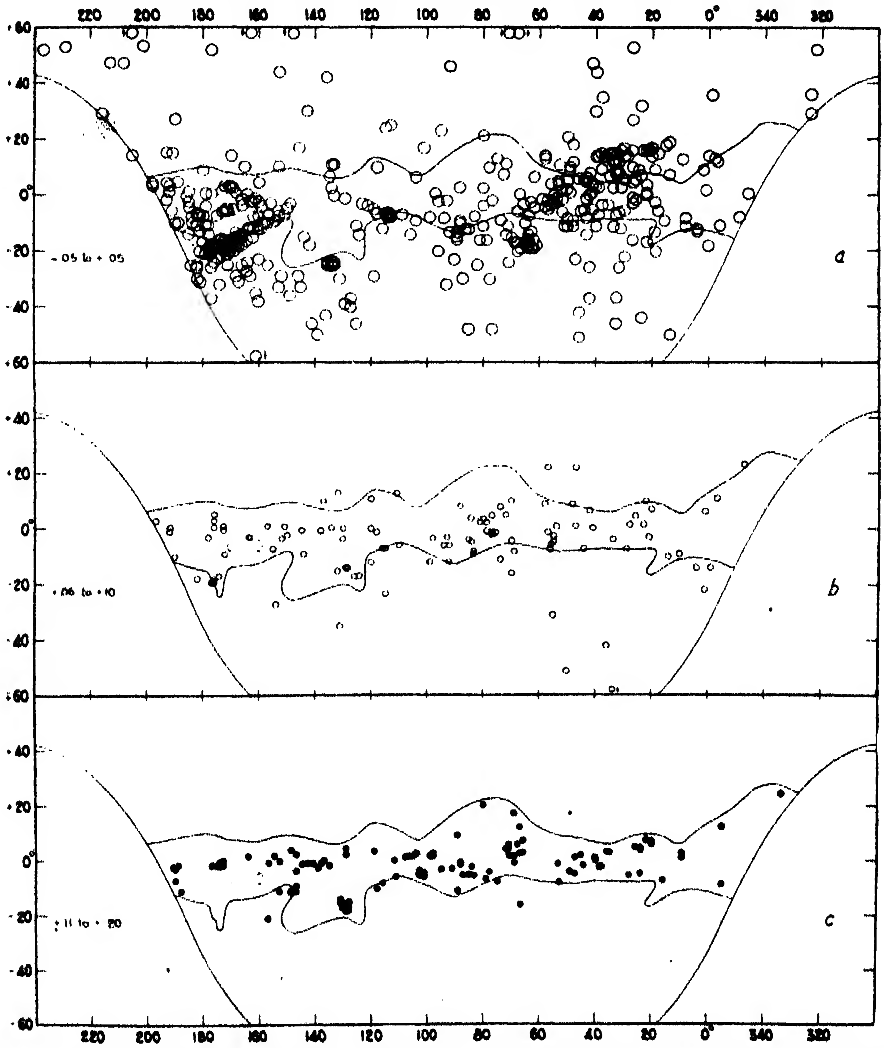

FIG. 7. COLORS OF B-STARS CHARGED ACCORDING TO GALACTIC LATITUDE AND LONGITUDE.

STARS OF NORMAL COLOR ARE REPRESENTED BY OPEN CIRCLES; REDDENED STARS BY BLACK CIRCLES. THE IRREGULAR OUTLINES MARK THE LIMITS BETWEEN WHICH NO OUTSIDE NEBULA CAN BE SEEN.

with the convention that the redder the star the larger is the black circle to represent it. As might be expected the extreme cases of coloration are found among the most distant or faintest stars, and from the form of the galaxy these are likely to appear at small angular distances from the median plane. The limits of the zone where Hubble finds practically no extra-galactic nebulae mark the region where we can not see out, so to speak, and it is in just this part of the sky where the coloring effect is found in the B-stars. It should be noted that Hubble's limits extend north and south many degrees from the middle line, and hence include not only the dark obscuring division but the whole bright band of the Milky Way and even areas beyond.

At longitudes 160° and 170°, roughly opposite the galactic center, Hubble has found two regions where a few nebulae can be detected on the photographs. That these places are "holes" with less absorbing or scattering material is confirmed by the fact that no strongly-colored B-stars have been found near the regions, even when the observations are carried to fainter magnitudes with the reflectors at Mount Wilson.

Study of Coloration

Although we learn from groups like the Pleiades, containing many stars at approximately the same distance from us, that there are wide variations in the intrinsic luminosities of stars having similar spectra, we can still get fair mean distances by averaging many stars, and

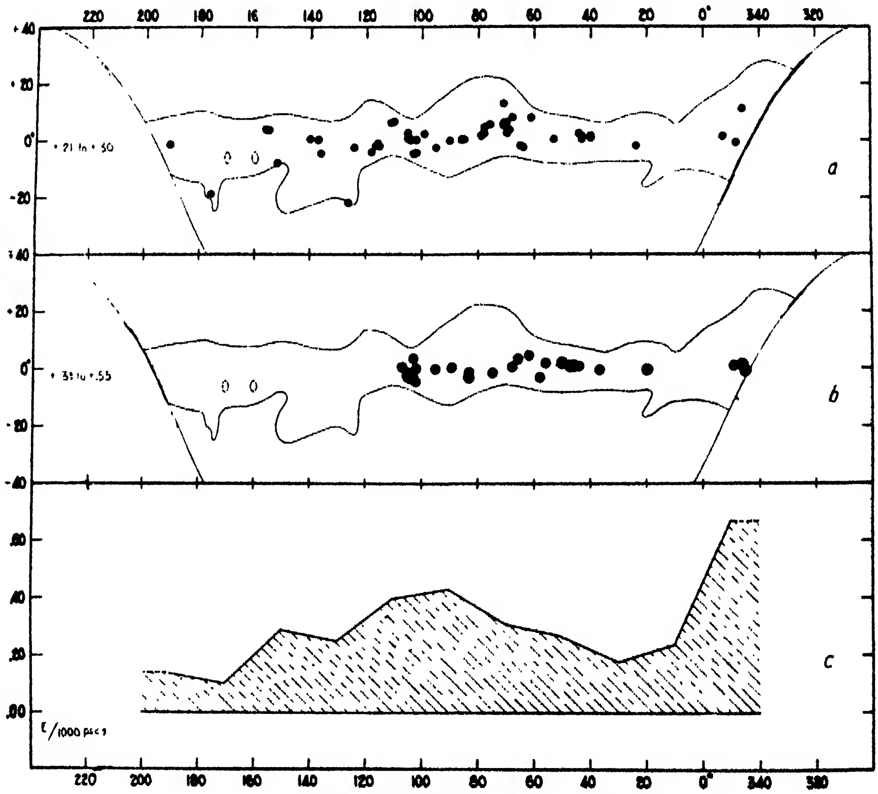

FIG. 8. (*A*) AND (*B*) THE REDDEST B-STARS.
SMALL ABSORPTION AT LONGITUDES GREATER THAN 110°, WITH "HOLES" AT 160° AND 170°.
(*C*) DENSITY OF THE DARK MATERIAL IN DIFFERENT DIRECTIONS, WITH MAXIMUM NEAR THE GALACTIC CENTER AT 330°.

FIG. 9. (*A*) AND (*B*) TWO EXPOSURES IN RATIO 16 TO 1 ON THE SAME GLOBULAR CLUSTER

SHOWING HYPOTHETICAL ABSORPTION OF 3 MAGNITUDES BY INTERVENING DARK MATERIAL.

in this fashion the amount of coloration per unit distance has been derived as is shown in the last diagram of Fig. 8.

The technical quantity, E/1000 pscs = Color-excess per thousand parsecs, is the measure of the amount of space-reddening in a distance of 3,000 light years. The diagram shows a maximum of color effect on the stars near the galactic center in Sagittarius, longitude 330°, with much less reddening in longitudes 120° to 200°—which include the winter constellations from Auriga to near Canis Major. Other observed differences in the amount of coloring are undoubtedly real, but the results may be affected by the lower limit of brightness to which the stars were observed.

The B-stars were chosen for tests of coloration because of their great luminosities, but the globular clusters, each with tens of thousands of stars, can be observed at distances many times greater than the individual stars. In fact, with the amplifier on the 100-inch telescope all the recognized globular clusters visible from the latitude of Mount Wilson can be measured satisfactorily for total light and color, as they are all brighter than the thirteenth magnitude while the instrument will reach to the fifteenth.

Though the composite color of the many stars in a globular cluster is not so definite a thing as the color of a single star, the effective ratio of blue to yellow for the different clusters corresponds to their average spectrum, which is of solar type, and it is found just as for the B-stars that clusters in high galactic latitudes are of normal hue, while those apparently near or in the Milky Way are strongly reddened. The greatest effect thus far found is illustrated in Fig. 9a and b, where the reddening is shown to correspond to a total absorption of 3 magnitudes or of 15/16 of the visual light of the cluster. The real distance of a cluster with this degree of absorption is only one fourth as great as would be inferred from the apparent brightness of stars of standard luminosity found within its borders.

The most colored B-stars which we have found in the Milky Way indicate an absorption of two stellar magnitudes, giving the factor 2.5 for the reduction of their computed distances. If obscuring effects of this size are evident in B-stars only 2,000 or 3,000 light-years from the sun, it would seem that objects still more distant along the median galactic plane

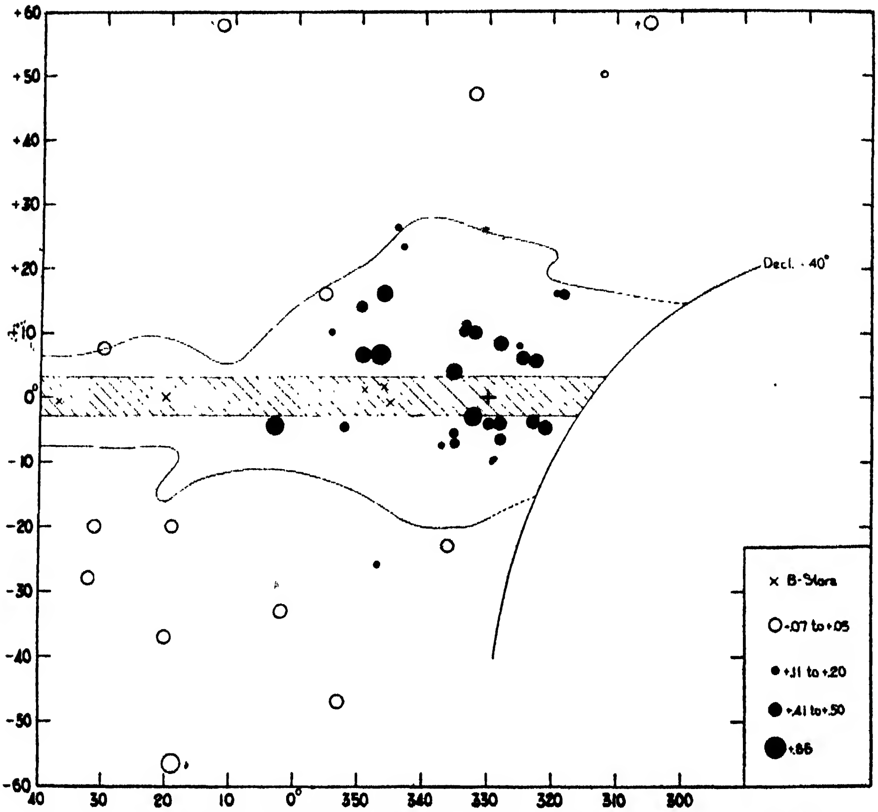

FIG. 10. GLOBULAR CLUSTERS NEAR THE CENTER OF THE GALAXY.
THE BLACK CIRCLES INDICATE INCREASED REDDENING IN LOW LATITUDE, WITH COMPLETE ABSENCE OF CLUSTERS IN THE SHADED ZONE. THE CROSS FOR THE CENTER IS THE SAME SIZE AS IN FIG. 1 LEFT AND RIGHT.

would be red enough to be quite striking to the eye.

Actually this is the case: we have often recognized a faint B-star with the 100-inch by its yellow if not ruddy color. The maximum effect would be to change the white of a star like Rigel to about the yellow of Arcturus. In the globular clusters, however, the individual stars are so faint and the combined glow so feeble, even in the field of the large reflector, that the red color, though conspicuous with the cell, is not apparent to the eye. In Fig. 10 are charted the clusters near the galactic center, observable at Mount Wilson but too low at Madison.

Conspicuous on the diagram are the widened bulge of Hubble's limits about the nucleus of the galaxy, the strong effect of space-reddening for clusters in low latitude, and the complete absence of globular clusters in a zone about seven degrees wide extending along the galactic equator. This significant and well-known absence of the clusters from the middle line is commonly ascribed to an absorption effect. Any other explanation seems forced, and the increased color of the clusters on the margin of the zone fits in perfectly with this idea.

The Dark Filling of Our Galaxy

It is probable that very few people have looked up in the southern sky on a summer's night and consciously said to

themselves, "There is the center of the galaxy." Even astronomers were reluctant to think of the Milky Way system being like one of the spiral nebulae, because there was no nucleus in sight. The trouble was that they were looking for something too small and too bright. The bulge of the nucleus, marked by the limits in Fig. 10, is some forty-five degrees across; it would extend half way from the horizon to the zenith, and photographs can show only part of the region on one plate.

Also the ordinary reproductions of negatives of the Milky Way and of the nebulae give an exaggerated impression of the surface brightness of the objects in the sky. The exposures of the plates of Fig. 1 (right) were about four hours, and of Fig. 3, seven hours. When seen directly through the telescope such nebulae are disappointingly faint. With all this in mind, the resemblance of the division of the Milky Way to the corresponding appearance of some of the nebulae is very striking to the naked eye, under the favorable conditions of a dark sky.

The conception of the appearance of our galaxy from the outside as a round flattened system with a dark region down the middle is well exemplified by the object in Fig. 11. The general form of the system has often been likened to that of a watch or bun, but perhaps it is better to change the figure to a "ham sandwich" to allow for the dark filling; and we are in the midst of the "ham." It should be remembered, however, that the stars do not thin out near the main plane; in fact, that is the region where they are probably thickest.

The presence of a thin absorbing layer of dark material concentrated near the middle of the galaxy, not more than a few hundred light years in thickness, was first emphasized by Trumpler from his studies of open clusters of stars distributed near the galactic plane. The work with the photoelectric cell has confirmed and extended his results.

In addition to the material which

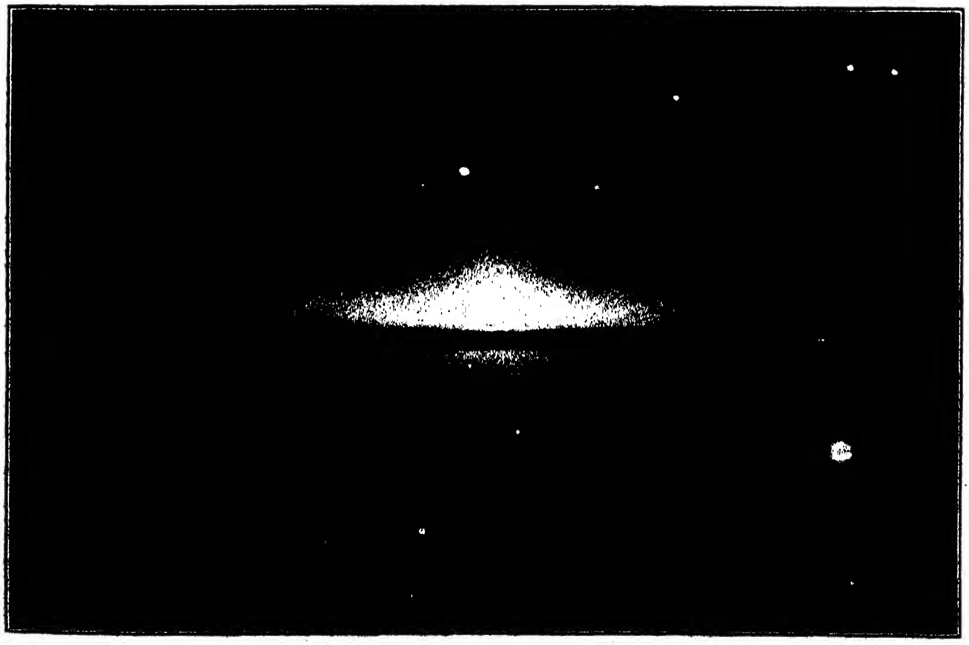

FIG. 11. THE NEBULA N.G.C. 4594.
ANOTHER GALAXY IN THE FORM OF A "HAM SANDWICH."

shuts out stars in the Milky Way, we now have ample evidences of smaller particles which give selective scattering near the same regions, but the picture is still incomplete. There is another whole dark galaxy or cloud in space, composed not of solid particles, but of atoms, largely ionized atoms of calcium. Where the large dust particles obstruct the light and the smaller ones scatter it, the calcium atoms produce only the selective absorption of a few lines in the spectra of stars seen through the cloud.

Here again the B-stars are the best objects for the tests, partly because of their great luminosity, but particularly because there are few or no atoms in their atmospheres that are producing the dark lines caused by the interstellar calcium. The lines in the spectra of B-stars have been used by Plaskett and Pearce to demonstrate that the calcium cloud partakes in the rotation of the galaxy about the same center in Sagittarius that is marked by the motions of the stars themselves.

There is one outstanding discrepancy, namely, that the B-stars with intense lines of interstellar calcium are not the stars that we find to be strongly reddened. We should naturally expect the stuff between the stars to be mixed up pretty well together, but this is apparently not the case. This lack of correlation between space reddening and calcium absorption has also been found by Elvey and Struve in photometric and spectroscopic observations of the same stars taken at Yerkes Observatory.

Just why this lack of agreement should exist is at present a puzzle, but it is probably not due to errors of observa-

FIG. 12. (*A*) REGION OF THE ANDROMEDA NEBULA,
PHOTOGRAPHED BY BARNARD WITH THE 10-INCH BRUCE TELESCOPE.

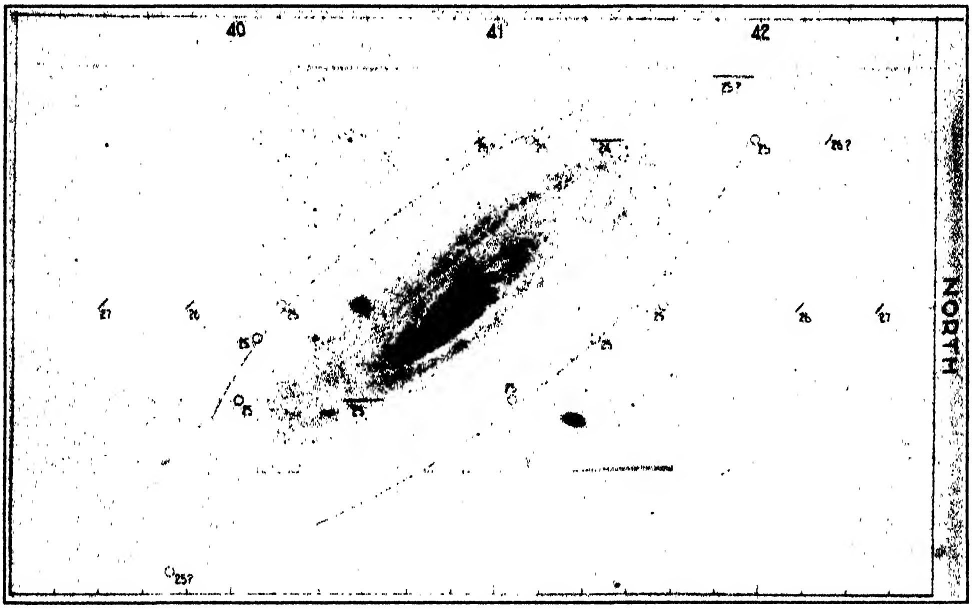

FIG. 12. (*B*) EXTENSION OF THE ANDROMEDA NEBULA.
THE NUMBERS GIVEN THE MEASURED INTENSITIES IN STELLAR MAGNITUDE PER SQUARE SECOND OF ARC. THE NEBULA IS 40 TIMES FAINTER AT 27 THAN AT 23. (NEGATIVE BY RITCHEY).

tion. There is some evidence that the calcium cloud is not as much condensed in a thin layer as the scattering dust, for when the B-stars are charted according to the intensity of the calcium lines, in diagrams similar to Figs. 7 and 8, the stars with strong absorption are much more widely dispersed in latitude. Taken altogether, the stuff between the stars, which is becoming increasingly evident, probably is of total mass as great or even greater than that of the stars themselves. The dark galaxy may turn out to be the major part of our system.

LIGHT INTENSITIES OF NEBULAE

The one difficulty with considering the Milky Way system as a galaxy similar to the numerous nebulae is that of size. The comparison is easiest made with a near and large object like the Andromeda nebula (Fig. 12a). From the apparent brightness of Cepheid variable stars, novae and other objects in this nebula, the distance is calculated to be about 800,000 light years, and from the apparent extent on the photographs the diameter is some 40,000 light years. With the galaxy 200,000 light years across, the discrepancy in the linear dimensions of the two systems was about five to one, but with allowance for the effect of dark material on the inferred extent of our own system we can bring the ratio down to two or three to one.

This nebula is far enough from the Milky Way so that we see it through only a small amount of absorbing dust, and hence its computed dimensions are but slightly affected, but if we could find that the nebula extends out farther than the pictures show, the difference between our galaxy and the nebula would be still further reduced. With this test in mind an effort was made by Dr. Whitford and myself during the past summer to measure the light of outlying regions of the nebula with the installation at Mount Wilson.

We are likely to forget that the limit for faint stars and nebulae that can be

reached by the eye, or especially by photography, is set not so much by the size of the instrument as by the diffuse light of the sky. Even on the darkest night at a mountain station there is a faint glow in the atmosphere, due largely to a permanent aurora, which exceeds the light from the stars. Otherwise the exposure of four hours for such a picture as Fig. 12a could be forty or even four hundred hours. For telescopes like the reflectors with focal ratio f : 5, an exposure of four or five hours is about as much as is advantageous; any additional time will produce simply more blackening of the plate from the general light of the sky.

In measuring the Andromeda nebula with the photoelectric cell the procedure was to compare the light of small areas near the nebula with regions of the sky several degrees distant. The galvanometer deflections were recorded at intervals along a north and south circle, and on subtraction of the mean deflection for sky alone, given by the outermost readings, from other deflections of sky plus nebula, the residual effects for the nebula were determined.

The results are charted in Fig. 12b, where the small circles marked 25 indicate to scale the area of sky measured, and are placed about the nebula where the intensity was found to be equivalent to stellar magnitude 25 per square second of arc. As the light of the sky alone was about 22.3 mag./sq. sec. it follows that the nebula at these points was only 1/12 as bright as the sky foreground, and similarly for magnitudes 26 and 27, as marked, the ratios of nebula to sky were 1/30 and 1/75, respectively.

In this method the cell can detect about 1 per cent. of the sky brightness, the limit being placed by stars in the field too faint for the observer to see when selecting regions for measurement. A definitive comparison of the sensitivity of the amplifier and the photographic plate has not been made, but it is known that the photographic limit for threshold images is about 25 mag./sq. sec., so the cell seems to be several times the more sensitive.

The rough outline of the nebula for intensity 25 is shown by the broken line of Fig. 12b, and even this intensity is beyond the limits of the photograph. A study of the regions along the apparent major axis of the nebula has not been completed, but in the areas measured the extension is at least double that shown on photographs. We may, therefore, anticipate that the overall diameter of this neighboring galaxy will turn out to be 80,000 light years instead of 40,000.

Other measures in and about the nebula give us a comparison with our own system. According to Seares, the surface brightness of the galaxy viewed from outside and in a direction at right angles to the main galactic plane would be 23.7 mag./sq. sec. This brightness is barely visible on the photograph of Andromeda, the central part of which is about 100 times brighter than the sun's region of the galaxy.

Just how bright our own system may be near the nucleus is difficult to estimate because of the dark material in that direction. The little circle at 25 mag./sq. sec. for Andromeda encompasses the light equivalent to 110,000 suns, and out at 27 on the diagram the figure is nearly 20,000.

At the center this same sized area includes about 75,000,000 suns, a figure large enough to raise the question whether so many stars could be packed in so small an area without some being in front of others. A simple calculation, however, will relieve us on that score. If our line of sight in the direction of the nucleus of the nebula would always hit the surface of a star, then this part of the nebula would appear to us as a brilliant object with the surface intensity of the sun. Actually this surface

brightness is 28 stellar magnitudes fainter than that of the sun, and it follows that the apparent spaces between the objects are 1.6×10^{11} times the area of the stars themselves. Thus there is still plenty of room between them.

Our Galaxy Predominant in Size

The nebula of Andromeda with its billion or more stars is one of the largest, if not the largest nebula, in sight. Perhaps the two companion objects in the photograph, apparently attendant nebulae, are more nearly typical of distant galaxies, but the main nebula is a close rival to our galactic system. In fact, the largest estimates for the Andromeda nebula exceed the moderate guesses for the galaxy. Lundmark places the nebula at about 1,500,000 light-years distance, which with the revised apparent diameter gives a real diameter of more than 150,000 light-years, or half again the size of the Milky Way system. The photoelectric cell has contributed to this comparison by helping to enlarge the nebula, and to decrease the estimate for the galaxy. Nevertheless, even with the uncertainty of dimensions in our own neighborhood, the galaxy still stands out as a continent among the islands, but not as great a continent nor the only one, as was formerly supposed.

Long ago men thought that the center of things was near the eastern end of the Mediterranean Sea. As the world grew larger it became a sphere, with other planets and the sun and stars revolving about the earth. Centuries were required to move the center from the earth to the sun, and only recently have we taken the sun away from the middle of the stellar system. Now we may have our proper place, but characteristically our own galaxy is predominant, surpassing everything else in size and importance. It is difficult to make the step, but ultimately we shall probably come to the conclusion that we live in just another galaxy, that's all.

THE DOMESTICATION OF ANIMALS

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Introduction

The domestication of animals holds an important place in the list of great things that mark the progress of man. Coinciding with the culmination of man's essays that led to planting, there are seen in rearing and agriculture the founding of two great bases of civilization.

There appear to have been three great phases of human experience with animals: (1) Animals as human congeners; (2) man as distinct from other animals; (3) animals selected and controlled by domestication.

Another may come in the invention of economic forms of animals. The first period extends over the whole time, including man's origin and development to the transition to the Neolithic. We know little more than that in the course of this long formative period there was a succession of animals appropriate to climatic periods of the glacial ages and long extinct.

The second period reveals what amounts to a revolution in human history in the Neolithic and its preparatory phases. Up to this time there was little hope that the genus Homo would achieve a notable destiny. In a few thousand years the indices of civilization were fixed. Man had separated widely in word, thought and deed from his animal roots and assumed his captaincy of nature. For helpers he began to domesticate animals, taking them out of their natural limits, changing their habits and otherwise adapting them to his own use.

Previously, we view man as still enmeshed with nature, his subsistence natural and his arts in stone, and environmental substances almost exclusively devoted to the capture of food animals. Suddenly, if the word is allowable, tribes that had incubated in a favored area in Asia after the close of the Glacial Period found themselves capable of purposeful migration, with all this implies as to advance and spread of culture.

These tribes swept into Europe and established there the Neolithic. This period is characterized by agriculture, domestication of animals, house building, village aggregations, pottery, wood, advanced utilization of fire, together with other arts. The Neolithic peoples brought with them the familiar domestic animals which we have inherited from them. It appears clear that these peoples domesticated animals at an early period, supposedly before 6000 B. C.

Association of Man and Animals

Domestication of animals is the culmination of a long series of experiences with various types of herbivorous mammals and of birds. The early domesticators learned of the particular qualifications that would lend themselves to the subjugation of species amenable to discipline.

The inference is that man, closely connected with animal life in his early stages, would acquire a complete fund of knowledge of the habits and psychology of his wild congeners. Such knowledge was a part of his useful, even essential woodcraft. The nature of animals guided him in attack and capture. Subsistence was the prime necessity leading man to prey on animals valuable for meat. The animals would be gregarious, numerous, and ranging in an environment suitable for hunting. These conditions are met with in the equidae and

bovidae. Without doubt these herbivores supplied the species that eventually would become domesticated.

Undoubtedly, however, these large animals would in the growth of man's culture come under domestication later than smaller mammals as the goat and pig, and perhaps domestic birds, as ducks and geese.

On the flanks of the wild herds we picture man pursuing the tactics of the primitive time—cutting out stray animals, dogies or bogged cattle as he could, keeping within the range of his prey. The seasonal forage migrations of the animals enforced man's migrations. These were not controlled until later, as in the story "Grass," which is a picture of the early herders transferring their flocks over the mountains.

The chief condition of herd existence is movement. The exigencies of delay in regard to parturition are set off by the short period of helplessness of the calf. Observation shows that in this state it is only a few hours until the calf can follow its mother. The calf soon acquires swiftness and it requires a speedy horse to keep up with a vigorous specimen.

All the evidence points out that the herder stage antedates all other regulated contacts of man with domesticable animals. It is logical here to rehabilitate the hunter stage of the older writers, but it must be said that the latter stage was not applicable as a concept of a form of life in all environments. The roots of agriculture and animal husbandry are quite distinct; the presence of animals as an adjunct of agriculture is a later condition in the latter industry. As suggested, herding is the older industry and, like agriculture, continues as a separate occupation pursued by an important section of the human race to this day.

The natural preparation of animals for domestication represents a long course of evolution. The ordering of mammals into carnivora, herbivora and other classes is the result of evolution in a general sense, connoting the results of a process of life phenomena not as yet understood.

On the entry of man into the animal enclave as one of the products of evolution we must place him in relation with the animal groups that it is his destiny to ward off, regulate and conquer. Whatever was the condition of the animal kingdom before man began his course, the changes since have been great. In some areas the changes have been prodigious and rapid compared with slow-moving nature.

Domestication

In treating of the origin of domestication it will be seen at once that the subject involves the distribution of man and domesticable animals, man's phase of culture, his adaptation for the art, embracing the psychology of the animals, and of man himself, and other lines for consideration.

Considering the major animals of potential use to man, hunting by tribes would precede domestication and would provide a background for future control. There may follow then the herding by pastoral tribes afoot and later with the aid of the dog and horse. At subsequent stages of cultural advance animals were confined within narrow limits by sedentary agricultural tribes utilizing the animal products and especially milk.

It is suggested that the acquisitions of man have been somewhat as follows:

Things near him needful	*Savage*
Things farther away but bounded	*Middle Savage*
Things beyond the rude boundaries	*Early Civilized*
Trade and exploration	*Middle Civilized*
Land ownership and domestication of animals and plants	*Civilized*
Metals, transportation, civil organization, law	*Lower Enlightened*
All arts and education	*Middle Enlightened*
Conquest of forces, thought in higher planes	*Upper Enlightened*

It is evident that man did not domesticate animals until he reached a certain stage of domestication himself. This stage for all races of men is not uniform, but is conditioned by various circumstances, such as the habits of the tribes, the presence of domesticable animals, the regional aspects and the like, and the stage of advance in culture.

The presence of domesticable animals depends on orographic conditions governing the range of such species. These conditions have changed often in human history since the last glacial epoch, placed by Peake and Fleure at about 4000 B. C. The changes have been important enough to regulate the distribution of man and animals over large areas of the Old World.

In general, domestication of useful animals begins when conditi ms are ripe for the handling and protection of flocks and herds. This, of course, represents a considerable advance in culture by man, and such a state of society is comparatively recent. The knowledge acquired on the art of domesticating animals was long in being brought together out of past experiences.

The date at which domesticated animals occur can not be ascertained with any degree of finality. It is not supposed that domestication took place all at once or in any one region, but it is true that the process was finished in a definite period of man's history. This period is characterized by a considerable human progress, in which appears agriculture, houses, pottery, wars of offense and other evidences of growth in culture.

There is no evidence of domestication of animals in the ages before the Neolithic. Evidence is therefore lost on the handling of harmless animals that may have haunted the environments of early man, as, for example, the pets of the Arawaks and other South American Indians. Commensal animals no doubt existed, such as those that waited on carnivores for a share of the catch. Of these the dog seems to have been early in hovering around the camps of man and perhaps the earliest in coming into domestication; note the skulking of the coyote and jackal.

The response of human society to the utilization of domestic animals varies from quite general to limited. On the one hand are seen herdsmen intimately connected with their flocks, using the soil only for grazing, and the farmer possessing a limited number of animals. These occupations are self-limiting. The herdsman can not tend flocks and till the soil, especially before the advent of fences. He ranges his herds free, following the seasonal growth of feed over the mountains or the plains. There is here no doubt some clew to the origin and development of domestication. There is also ground for the separation of groups of men into pastoral and gregarious.

As to domestication of certain animals at more than one place and time there is some question. There is a tendency of pressure of civilization to limit or draw in animal life. Interference of natural range and capture and confinement may result in domestication. To answer the question of more important domestic animals research must be made on the geographical range of animals and thus their occurrence in localities where domestication was first practised. In this case each animal must be considered.

Of the interval between the domestication of useful animals in the Neolithic and their appearance and their utilization by peoples on the frontiers of history we know little beyond the distribution of such animals. At every advance of this frontier, however, the chief domestic animals are found to accompany the culture of the ancient civilizations using the prime metals.

"The horse was known in Babylonia as early as the time of Hammurabi" (2124–2081 B. C.).[1] Dr. Smith states

[1] Sidney Smith, "Early History of Assyria," pp. 213–214, N. Y., 1930.

that the Babylonians believed that the horse was known as early as 2500 B. C. He also states that the Hurri of Indo-European stock and believers in Hindu gods were great horsemen. This would suggest that the horse came to the west from India.

A picture of primitive man in association with wild cattle is given in the Sumerian epic of Gilgimash. Eukidu, a Sumerian god, was in the beginning a typical savage watering at the springs and feeding with the cattle. When Enkidu was taken into the city and associated with men the wild cattle no longer recognized him, but fled away from him.[2]

A study of the economic animals leads to the surmise that these were brought under domestication in Asia. There is no doubt on this point as to the camel, elephant, yak and water buffalo. These may be considered local domestications of special animals inhabiting special areas. Changes from hunter to pastoral and sedentary life seems to have been less affected by climatic causes in Asia than in Europe. Studies of the domestication lead to Asia as the center of distribution of most of the major domestic animals. The locality where this took place is probably east of the Caspian, known as Eastern Turkistan.

Some suggestions as to the domestication of animals were presented in an article "The Development of Agriculture," published in THE SCIENTIFIC MONTHLY for October, 1929, pp. 301–310, and a more popular account in "The Story of Fire."[3] These referred to contacts of man with animals of various mammal groups whose habits and make-up would put them in line for future domestication.

As set forth, the preparation of the man stem, aiding him to become man, is paralleled in the development of certain herbivorous mammals that subsist on what may be called primary food. These forms entering into domestication have originated by a process of selection. The early stages of this selection, artificially influenced by man and involving submission by the animals, can only be conjectured.

We know, however, that the natural association with wild animals of the Pleistocene was not of a type to foster domestication. The horse, wild cattle and smaller mammals, marked in a sense for domestication, were hunted for meat, skins and other useful products. Their diffusion necessarily was not uniform as to time and area, but the mammals mentioned survived into the age when the circumstances of human culture permitted the application of domestication. At this time the suitability and adaptability of animals for domestication was gauged, as suggested, by the experiences of a long period of association in what has been called the stage of savagery.

The fear that is engendered in animals by happenings out of the ordinary is a protective device. In conditions where, for a period of undetermined length, animals are not subjected to fear the protective device is obliterated, becoming a useless function. Many instances of this have been observed, and their occurrence is noted as extra normal by believers in the tooth and claw order of nature. Observers in new country have recorded with expressions of surprise the lack of fear by animals.

It is true that discharge of firearms, the light and smoke of camp-fires very soon puts an end to an edenic simplicity like this. Fear is displayed, often in an exaggerated degree, and at the same time the animals become educated in evading the dangers. It is seeen that the inventions of man for the capture of animals require increasing refinements to be effective. There is no doubt that most animals are apt students in the school of experience.

[2] Stephen H. Langdon in "Mythology of All Races," vol. 5, The Semites, p. 238, N. Y., 1931.

[3] Doubleday, Doran and Co., p. 27, 1930.

There still remain in remote parts zones of peace where animals are unaccustomed to fear. One such zone was found in Tibet by naturalists on the British Mt. Everest Expedition. In this case the naturalists were permitted to observe the animals, but not to collect or disturb them, these rules being promulgated by the Tibetan authorities. Another instance, not man-controlled, was brought to my attention by Henry B. Collins, Jr., who observed the lack of fear among the birds and animals during his explorations on St. Lawrence Island, Alaska.

The adjustment of tribes of men and the animals in their environment is also noted. The announcement of "plenty of game" is not inconsistent to the presence of population, that is, of natives whose predilections and needs are not those of races called enlightened, who are only satisfied with extermination of the fauna.

The above leads to the generalization that domestication is not the province of cruel and fear-engendering men. Domestication came about in zones of peace and was accomplished by peaceful men through kindly methods.

The coming together of such fortuitous circumstances as such animals suitable for domestication and men of the peaceful, patient type undoubtedly was found in Asia, where our domestic animals originated.

An examination of the degree of domestication of various animals leads to the view that tolerance, semi-domestication and domestication are the classes into which they may be divided. The camel is an example of the first class. The carabao is only semi-domesticated, given to stampedes, is individual and requires care, and on the whole is just tolerant of man.

In general, the care of animals depends on their stage of domestication and also their physiological make-up, psychology and habits.

When man hunted animals there was begun strategy by which numbers could be surrounded. At a later stage this strategy was continued and finally adapted to the taking of animals for domestication. Animals of smaller size, as goats and sheep, being huddle animals, could be cared for more easily than the herd animals ranging over a wide feeding ground. With the herd there was less personal touch than with the sheep, which could be led or controlled by a shepherd.

The handling of the flocks and herds required at the beginning of the industry a knowledge of the habits and reactions of each species. In the controlling of animals we have several appliances of early invention. Mention may be made of fixed adjuncts as fences, corrals, pockets, gates, barns and outhouses. Free adjuncts would be in part lassos, cords, whip, goads, crook, harness and saddles. In handling animals we note nose snubbers and hobbles.

Animal aids also played a prominent part in the control of animals, the dog especially. The horse after its domestication and use for riding was always a most valuable aid in the control of herd animals, though not indispensable, as man has fleetness of foot in a high degree. Other domesticated animals are used to decoy or force in other beasts, as with elephant captors. Sometimes the sex urge is used.

Man has a decided aid in promoting domestication by what may be called the food whip. He has great power in giving and withholding food and water to animals. We do not know when this method of coercion was applied to domestication, but it must have been primary. Captured animals go on a hunger strike, but presently come to accept food from man. By stages the food giving becomes a customary thing and the animal is well on the way to being domesticated. The habit of receiving food be-

comes a part of animal experience and strengthens the dependence on man.

It is observed that stress often softens the wildness of animals, as in the winter the wild elk of Yellowstone Park coming down from the mountains to limited feeding grounds become quite tolerant of man. Drought, fires, storms, earthquakes, cold, heat, overgrazing—all have their problems for animals and give man advantage in beginning domestication.

The killing of feral animals by man with his superior weapons is also seen to be an aid in the amelioration of herd animals. In this respect man has unconsciously paved the way to the art of domestication.

Man with his superior intelligence could take advantage of the hampering of animals by the terrane. It may justifiably admit of supposing that sheep and goats could be captured in pockets in the mountains or during heavy snows.

Many tribes of the world are destitute of domestic animals and are in this respect like the tribes in the early periods before domestic animals were acquired. Notably they were absent in Australia, not even the almost universal dog being found there among the wild tribes. The Negritos of the Philippines had no dog. Negroid Africa was gradually supplied with domestic animals, and even now some tribes have none. Much of the New World possessed only the domesticated dog.

Effects of Domestication

When the art of domestication began it was not realized what rapid evolutionary processes would follow on the animals themselves. The subject of animal variation is of fascinating interest, but can only be mentioned here.

The effects of domestication due to the segregation and working, that is, handling, of animals may have been apparent in a comparatively short time. With increasing knowledge man laid the foundation of animal industry by selection of variations, breeding, castration of unneeded males, separation of age and sex groups, feeding and "working." The industry represents the trial and error of thousands of years and is always with human advance accumulating new knowledge whose bounds no one can predict.

Pets and Tolerated Animals

The adoption of animals as pets offers an interesting chapter, throwing light perhaps on the processes of domestication treated in this paper. The dominance of man over animals, growing more and more from the earliest periods of which we know, would indicate the possession of pets and tolerated animals at almost all periods. The abstraction from the environment of small animals as pets and commensals is usually a temporary matter, and it is likely that for the most part little of economic value ensues. The harboring of pets seems to be a human trait, but is reflected in nature by various contacts of one animal with another.

There is an infinite number of examples of pet domestication, some dating far in the past. Conditions in northwestern South America give rise to the acquisition of many pets. Travelers remark on the number of birds and other animals freely moving about in the palm-thatched communal houses of the Caribs and Arawaks of British Guiana. Hunters in the jungle, armed with bow and blowgun, preserve the silence of the dark forest. The animals are not frightened, as remarked on the preserves in Tibet.

There are many instances where birds are confined for special uses, notably for feathers. The turkey of the Pueblo Indians is not eaten, but is kept as living supply of ceremonially pure feathers and these birds are very tame. The eagle is caged by the Zuni Indians for the same purpose, but this bird is untamable.

It seems that the economically useful

birds, like the chicken, may have been brought into domestication through the pet stage. Eggs are a bird hazard, and where the knowledge of artificial incubation became known domestication was well to the fore.

It seems quite reasonable that the dog at first was a tolerated animal that had attached himself to the camps of man as a consumer of offal. The dog as a hanger-on policed the outskirts, and his primary value was watchfulness and the sounding of an alarm when animals or enemies approached. Gradually, and likely by the pet approach, the dog became closely allied to man. Rightly the general opinion is that the dog was the first domesticated animal. In every stage of man's culture the dog has fitted in an almost indispensable part.

There may be some connection between the feature of animals in cult and domestication. There is no selection on this basis, feral as well as domesticated animals appear in the series. The selecting of cult animals was not a haphazard matter but was influenced primarily by respect for or fear of animals whose qualities were recognized through the ancient contacts. This may give a clew to the origin of animals in cult. It will be seen that the idea of fierceness and strength preponderates in cult animals chosen to this day. Domestic animals in cult have a wide usage—for example, the cow, bull and dog in Egypt.

Clearly the progress of man has been much assisted by the possession of domestic animals. The hampering effect also should be noted, but the counter value in giving man a basis of subsistence and the impedimenta of possession and care of his charges, tending to enforce a more stable method of living, is likewise an important factor in his progress.

In this progress the period at which the correlation of vegetal food and animal meat and milk food tended greatly to foster the well-being of man. This is notable in civic organization, bringing the herder and agriculturist together as elements in the culture complex. The growth of society in regard to the surroundings of domestic animals may be considered as for herdsmen only, many of one or more kinds; cultivators, fewer to many; villagers, few; and city dwellers, few or none.

The orderly migration of man was facilitated by the possession of domestic animals. At first the movement would be with the grazing herd. At a later stage animals would be used for riding and traction. In war the provisions would be transported on the hoof.

THE NEED FOR A THIRTEENTH MONTH

By M. N. STILES[1]

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THE UNIFORM MONTH OF THE 13 MONTHS PLAN
Every Month 4 Weeks

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

IN considering the reform of the calendar, certain things should be kept in mind:

(1) Calendar reform no longer has to be the business of astronomers, who on occasions of previous reforms were the chief authorities consulted. The changes with which they dealt had to do with adjusting the calendar to the length of the solar year. That task was finally accomplished with the Gregorian reform of 1582. The reforms now proposed have nothing to do with astronomical equations for the solar year, but with the composition and arrangement of the calendar's months and weeks within the solar year. It is purely a problem of simple arithmetic responding to economic and social considerations arising from the use of the months and weeks.

(2) The demand for improvement has arisen chiefly because of the radical changes in our economic and social life that have occurred during the last one hundred and fifty years. These changes have speeded up our progress and thereby made it necessary to measure and study it in *short periods of time,* particularly our economic progress. In consequence, because the shorter periods available—the months and the weeks—are hodge-podge in their composition and arrangement, the calendar has become a hindrance rather than a help to progress. The months are not only unequal (31, 30, 29 or 28 days) but (excepting February) contain more than a whole number of weeks, and, in addition, incessantly change in their weekday composition. They are not, in any way, comparable units.

Practical economic convenience is the impelling motive of the movement plus social convenience. Any reform that can not achieve the maximum practical economic and social improvements surely is not worth while. To ask the

MONTHS OF THE EQUALIZED QUARTERS PLAN

January, April, July, October

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February, May, August, November

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

March, June, September, December

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

[1] Mr. Stiles was a delegate of the National Committee on Calendar Simplification for the United States to the first International Conference on Calendar Reform at Geneva in 1931.

world to undergo the disturbance of change for a partial reform and minimum benefit is asking too much.

(3) In modern life the month and the week are the most used units of the calendar. In our personal affairs we scarcely give thought to the quarters of the year as a measure of time; we date and calculate by the month and the week. In the affairs of business the use of the month and the week as measures of performance and for comparative reports and statistics is immeasurably greater than that of quarters. Business no longer waits for a quarter of a year to elapse before finding out where it stands. Hence it is far more important that the months be equalized and that each be a multiple of the week than to have a mere equalization of the quarters, as proposed by some. Scientific data based on periods of time is likewise measured far more in months and weeks than quarters.

(4) In choosing a plan of reform, practical experience is the test of worth. More than 400 large businesses in the United States and Canada have within recent years adopted private business calendars consisting of 13 equal "months" of four weeks each. They use these in order to escape the disadvantages of the 31 and 30-day months and broken weeks of the present calendar for their accounting, statistical reports and business management. The business use of the 13 four-week periods in Europe is also growing. Should successful experience with a plan of calendar reform be left out of consideration in comparing it with a plan that has never been tried?

The Two Plans

The 13 months principle of reform, proposed for universal adoption as a fixed perpetual calendar, is designed to meet the compelling economic and social requirements for equal months. A 13th month is introduced because, without abandoning the use of the 7-day week, equal months of four weeks each can be secured in no other way. The alternative proposal for a fixed calendar, which merely equalizes the quarters in order to keep the traditional 12 months, can not correct the inequality in the lengths of the months, can not provide for months containing a whole number of weeks, can not prevent changes in the week-day composition of the months from one month to the next. This is because its months consist of 30 or 31 days and have fractional parts of weeks.

Let the features of difference in the structure of the 13 equal months plan and the 12 unequal months equalized quarters plan be compared:

The 13 months calendar divides the year into months of four weeks each. The names of the present 12 months are retained. The additional month, called "Sol," is placed in the middle of the year, between June and July, in order to disturb as little as possible the positions of the present months within the year. Calendrically, December has 29 days and the last week of that month has eight days. This eighth day is given the non-week-day name of "Year Day," to be dated December 29, and would be observed as a holiday. In leap years the last week of June has eight days with the last day given the name of "Leap Day," dated June 29, and would likewise be observed as a holiday.

Practically a 364 day business year is thus created, for the most of our business activities. Each month then becomes an exact multiple of the week and, as nearly as nature will permit, each month is a sub-multiple of the calendar year, and an exact sub-multiple of the 364 day business year. In terms of months, the quarters do not contain a whole number of months, but each quarter has exactly 13 weeks. Each year would begin on Sunday. Each month

would begin on Sunday. Each quarter would begin on Sunday. Each day of the week in each month would fall perpetually on the same four recurring dates. This arrangement is the nearest possible to a perfectly uniform, perpetual solar calendar that can be devised without abandoning the use of the seven-day week.

In contrast, the 12 months plan is limited to making only the quarters of the year uniform. This is done by shifting seven dates, which alter the lengths of five months in such a way that each quarter will contain one month of 31 days and two of 30 days. The "Year Day" is introduced at the end of the year and "Leap Day" in the middle of the year as in the 13 months plan.

Each year would begin on Sunday and the first month of each quarter would begin on Sunday, but the second month would begin on Wednesday and the third on Friday, so that in each succeeding month throughout the year the week-days would fall on different dates. The quarters are equal, each with 13 weeks, but the inequality among the months is perpetuated. No month is a multiple of the week. The glaring defect of broken weeks at the beginning and end of months is perpetuated. There would be sixteen broken weeks in every year. The 31 and 30-day months are in neither case a sub-multiple of the 364 day business year, nor are they as nearly a sub-multiple of the calendar year as are the months of the 13 months plan.

The Practical Requirements

Notwithstanding the defects of the 12 months plan, its advocates urge that it be chosen by governments for submission to their legislatures on the ground that the 13 months plan would not be accepted by the public. A calendar introducing another month would be "too revolutionary." They place much emphasis, too, on the indivisibility of 13 as an objection to 13 months. They also argue that making the calendar perpetual and limiting the changes to equalizing the quarters will effect all the improvements that are essential.

To those who have given but casual thought to the question of calendar improvement and to those not practically familiar with its bearing on business life, the 12 months equalized quarters compromise has a plausible appeal. Without doubt, too, it appeals to the ultra-conservative mind, to those who approach the question from an academic view-point, to those influenced by the superstitions of numerology and to the ultra-sentimental. But from the standpoint of the practical work-a-day world, it is easy to show that the 13 months plan alone meets the practical requirements; that the alternative proposal demands that the public undergo the disturbance of a change without commensurate benefit, and, if adopted, would leave to posterity the task of another revision.

From the economic standpoint the 13 months plan alone can meet the two following requirements.

(1) Business comparability of any month with the corresponding month of previous years.

(2) Business comparability between different months of the same year.

This is simply because each month has four weeks, composed of the same number of the same kind of business days (barring holidays which are present in any calendar).

The 12 months equalized quarters plan meets only the first. It can not establish comparability between different months of the same year because (a) Four of its months have 31 days and eight have 30 days. (b) Eight of its months have fractions of one week and four have fractions of two weeks. (c) In all of its months two or three days of the week variously occur five

times, such as five Saturdays, five Sundays, etc., causing variations in the total business value of each month.

Advocates of the 12 months plan excuse the lack of comparability between one month and another by saying that such comparisons are not essential. They say that it is of paramount value to compare August, 1933, with August, 1932, for example, but is of little value to compare August, 1933, with July, 1933.

If this claim were valid, if comparisons only between months of different years were of paramount value, very little reflection will show that it would not be necessary to change the calendar at all, except in two slight particulars. We need only to give December 31 of the *present* calendar the name of "Year Day" and February 29 the name of "Leap Day"; in other words, simply make the present calendar a perpetual calendar, and the purpose of securing comparisons between months of different years is fully accomplished.

It must be quite clear that if without other change these two specially named days be introduced into the present calendar, every year can be made to begin on Sunday and the annual shifting of the days of the week to different dates in each month will cease. Each month will then have its exact counterpart in every year as to order, number and kind of days of the week it contains. Therefore, correspondingly named months in the present calendar will be exactly comparable.

What then is the use of the new 30 and 31-day months of the 12 months plan? Why cause the disturbance of rearranging the months when the desired comparisons between the same months of different years can be secured by the far simpler and less disturbing expedient described above?

The obvious fact is that this rearrangement is made to secure the equalization of the quarters and in proposing this and pointing to it as an advantage, the advocates of the 12 months plan concede that, at least to that extent, equalization of periods *within* the year does have value.

But equalization of the quarters is as far as the 12 months plan can go in producing comparable periods *within* the year. The advocates of the 13 equal months plan show that this does not go far enough to be worth the change.

Worth-whileness

First, from the standpoint of comparability within the year, the mere equalization of the quarters of the year meets no compelling economic requirement, because the use of the quarter of the year as a business time unit is exceedingly small compared with the month and because the quarters are already nearly equal in the present calendar.

Second, while accurate comparability between corresponding months of *different* years is an essential requirement of any reform of the calendar, accurate comparability between months of the *same* year is equally essential, if not more so.

The sound reason for these statements is that a vast number of comparisons between months in the same year are now used in our economic life, and that such comparisons would be universally used if the months were equal. In a multitude of businesses profit and loss accounts are compiled by the months and compared not only with the same month a year ago, but with previous months of the same year. Statistical reports such as those of sales and production are similarly compared as a general rule. One need only scan the financial pages of newspapers, the published statistics of trade associations in trade magazines and the business statistics issued each month by the Department of Commerce to find that in most of them comparisons are made with the

previous month as well as between the corresponding month of the previous year. In some cases they are adjusted for calendar-caused distortions, in others given for what they are worth. Innumerable charts and graphs are constantly being prepared to show monthly trends within the year.

An outstanding example of month to month comparisons of vital importance to our economic life is the monthly statistics of foreign trade and the resulting changes in the trade balance, frequently distorted when there are five week-end sailing dates in one month compared with four in the previous month.

Importance of the Week

Furthermore, a multitude of statistics are now based *on the week*. These can not be correlated with the months of the present calendar nor could they be with the months of the 12 months plan. The fact is that in many businesses where *weekly* statistics of sales, production, etc., are essential to keep close track of performance and of current trends, and where *monthly* statistics are also essential for monthly financial statements, the splitting of weeks at the beginning and end of months requires extra labor that would be eliminated if four weeks coincided with a month. This defect of the present calendar is one of the reasons why the use of the 13 months business calendar is growing.

Again excusing the inequality of the months of the 12 months plan the claim is made that they are practically comparable with one another because each has twenty-six working days. This claim is not, from a business standpoint, a valid one, because of the different business values of the days of the week.

For example, March of the 12 months plan has five Saturdays and February only four. The retail trade—chain stores, department stores, grocery stores, etc.—do a large per cent. of their business on Saturday.

March likewise has five Fridays and February four. Evening newspapers get the largest portion of their advertising on Fridays.

March has four Wednesdays and Thursdays, but February has five. Hotels get the best patronage on Wednesdays and Thursdays.

Thus monthly comparisons within the year would continue confusing for a multitude of businesses.

Further, if the five-day working week be adopted the comparability of consecutive months would be even more confusing. Again for those industries which operate *every* day of the week such as transportation, public utilities, moving-picture houses, steel and iron mills, etc., the twenty-six work-day claim has no point whatever.

Again, consider the use of the months within the year for the purposes of budgetary control and compare the simplicity of apportioning expenses to months the same in length and composition with the difficulties of doing the same to months of unequal length and varying composition.

In sum, were the 12 months plan to be adopted, only part of the job would be done. August of this year, for example, would be truly comparable with August of last year, but not with July. This serious defect of the 12 months plan for economic uses can not be disputed and is so because, except for the rare business for which the seven days of the week are all the same, each successive month of that plan has a changed comparative value because of its different week-day composition. Why perpetuate it?

Moreover, it is obvious that unless it is a perpetual calendar (to which there is religious objection from seventh day Sabbath keepers) the 12 months plan practically loses *all* its value. Deprived of "Year Day" and "Leap Day" there would be an incessant change in the week-day composition of all its months

from year to year as well as within the same year, just as in the present calendar, with the result that its year-to-year comparability between months would be lost entirely and thereby nothing left but a mere equalization of the number of days in the quarters, 91, 91, 91 and 92 instead of 90, 91, 92 and 92 as at present. The difference involves a change in seven dates, but what is the use of changing seven dates when the mere equalization of the quarters can be achieved with much less disturbance, *simply by transferring August 31 to February 29?*

On the other hand, the 13 months division without "Year Day" and "Leap Day" still remains worth while because it can achieve a large percentage of the benefits of the reform. There would be four weeks in each month containing the same number of the same kind of days except December with an extra day each year and June with an extra day in leap years. The order of these days in each month would, of course, change each year and the holidays would change to different days of the week (Thanksgiving and Labor Day to different dates) but the months would be comparable just as are the four-week periods of private business calendars.

The Indivisibility of 13 Months

Notwithstanding the indisputable fact that throughout our economic life, the month and the week are by far the most used periods of the calendar, the 13 equal months plan is assailed as impracticable on the ground that "quarterly statements are a fixture in present day business and finance," and that since 13 months are not divisible into quarters, the preparation of such statements would present difficulties.

The answer to this criticism is that if it were true that the business of the country were exclusively accounted for on the quarterly basis, there would be no good business reason for adopting the 13 equal months plan.

Many businesses, it is true, issue quarterly financial statements, but for what purpose? Primarily for the information of their stockholders, their bankers, and the investing public, to show the condition of the company. But no modern business could possibly be successful if its management allowed three months to pass before gaining knowledge of the results of its performance from time to time within that period. This is the reason for comparative monthly reports of sales, production, operating and other costs, and for monthly profit and loss statements that are now so generally in use. The quarterly report is but a recapitulation of these working reports for shorter periods.

But even as recapitulations, are financial statements strictly by quarters of the year essential? Are they so vital to our business life that it is more essential as a method of calendar reform to equalize the quarters than to equalize the more frequently used months? It is significant that some users of the 13 months business calendar, who formerly issued quarterly financial statements, have abandoned them and use only monthly and annual statements. Others find the purpose of quarterly statements —the financial condition of the company —is as well served by making them at the end of 3, 3, 3 and 4 month periods. Incidentally the New York Stock Exchange accepts such statements from companies using the 13-period division.

The Indivisibility of 31 Days

The objection to a year of 13 months as not being divisible into quarters is largely psychological. It comes from the habit of thinking of the calendar as constructed of months without consideration of the fact that the calendar also contains days and weeks which enter into the composition of these months

and of the year. Consciously or unconsciously the equalized quarters advocates fit their arguments into this psychology. When they object that a 13 months year is not divisible by four, they ignore *the fact that 31 and 30-day months are also not divisible by four.* They stress the fact that you can quarter their year and forget the fact that you can not quarter their months.

Now in calendar reform, the fact has to be recognized that it is mathematically impossible to have a calendar in which, while preserving the seven-day week, the year may be quartered into months and the months quartered into weeks. You can not have both together. A choice must be made between them. At the risk of laboring the point, I repeat that the most used divisions of the calendar are the month and the week, from which it follows that the benefits that would be derived from being able to quarter the months into weeks would overwhelmingly exceed those that would come from a slightly more accurate quartering of the years into months.

The difference between any of the 90, 91, 92 and 92-day quarters of the present calendar and the 91-day quarters of the equalized quarters plan is scarcely more than 1 per cent. But 31 and 30-day months can not be quartered into weeks without leaving a remainder of 42 and 28 per cent. of a week respectively.

For the Future or the Past?

The criticism is also made that from the statistical standpoint comparisons of the 28-day months of the 13 months calendar with the months of the past would be of little value without laborious and costly recomputation, and that in many cases it would be impossible to convert records of the past into records with which records under the new calendar could be compared. Particularly during the next few years, it is argued, it is essential that economists and business men have all the aid possible from past business records.

To quote one critic: "A radical change of the calendar [that of 28-day months] would seriously reduce the usefulness of those records and thus hamper the adjustment of business to world needs at a critical time in the advance of civilization." This, it is contended, would not be the case under the 12 months plan, because "comparisons for any month in the new 12 months plan, with those of corresponding months under the present calendar would not be seriously interfered with. Direct comparison of unreduced monthly figures for corresponding months would in many cases be satisfactorily accurate, and after a lapse of a few years, so that comparisons were entirely within the new calendar, they would be entirely accurate."

Before coming to the points of this criticism, let it be said that as an argument against the adoption of the 28-day months of the 13 months calendar, they would have a certain amount of merit were the change to be made without preparation for it, but as an argument for the adoption of the 31 and 30-day months of the 12 months plan, they provoke a smile from the 13 months calendar advocates.

We are here told in effect that the resemblance between the months of the new calendar and the old would be so close that the change would make little difference; accurate comparisons between corresponding months would be gained without a serious break in the continuity of statistics. Very good, but why change *any* of the months and upset dates when as previously pointed out the desired accuracy can be secured simply by leaving the months as they are and inserting "Year Day" and "Leap Day" to make the calendar perpetual. There would thus be even less interference with past comparisons, and all the advantage claimed in this respect

for the 12 months plan would be secured. Why give February 30 days, when its present 28 days will do just as well for year by year comparisons in the future and much better for the past? Clearly, from the standpoint of the criticism in question, the calendrical structure which its authors present for avoiding a supposedly serious break with the past is adorned with superfluous embellishment.

The Firm Foundation

But let us see if the break in the continuity of statistics which would be caused by the adoption of 28-day months would be as serious as alleged. In the first place, the present depression, and prior to that the war, have shown that long time economic statistics are of no great comparative value. There is a sad humor about this. Too many underlying conditions have changed, too many bases upon which the statistics were built have risen or fallen to different levels to give long ago business records any important practical face value in comparing them with the present, unless accurate allowances can be made. In any case—and this is the point that does not seem to be perceived —*long ago statistics are rarely compared by months, they are compared by years.* Who compares the price index, sales record, manufacturing output or profit and loss account of December, 1932, with the same for December, 1922, or December, 1912, unless it be for curiosity. The view as far back as that is to the *years,* not the months. It does not seem to be realized that the use and importance of monthly comparisons lie almost wholly in their disclosure of the changes and trends *from one year to the next and within the current year.* It is chiefly from these data of the immediate past that business makes its decisions for the immediate future.

Five years is certainly the extreme limit of use for individual monthly comparisons in the business world, and to say that the value of long time statistics, needed only for cycles and trends over a series of years, would be seriously reduced unless recomputed in terms of 28-day months can not be admitted as true.

We have left then to consider only the relatively short period immediately prior to the date for the revised calendar to go into effect. Is it to be supposed that our economic life would make no preparation for the change? Should an international agreement be reached in 1935 to put the 13 months calendar into effect in 1939, is it to be supposed that business would do nothing in the meantime to adjust its statistical data to the new months? Naturally it would do so, and in different cases it would do differently according to the requirements. Undoubtedly in most cases the change would be anticipated by adopting the 13-period division of the year for statistical purposes as soon as possible, as has already been done by hundreds of businesses in this country and abroad. In some cases undoubtedly two sets of records would be kept, one on the present calendar and one on the new, for one, two or three years prior to 1939. (In the age of bookkeeping machines this is not so laborious as may be supposed.) In others it would be found more desirable to "start from scratch" as did many businesses now using the 13-period division, when they made the change and put up with the temporary inadequacy of their comparisons for the sake of permanent advantage.

Thus it is seen that the break in the continuity of statistics would by no means have the serious effect upon their utility that is imagined.

And when calendar reform is tied up with present economic conditions as indeed it is by those who advocate early adoption of the 13 months plan as a means of closer scrutiny of business costs and the direction of trends, it is easy to

see that the short time monthly comparisons have by far their most important value as between and within the years of the immediate future, rather than between those years and the years either of the immediate or distant past. This service for the future, as has been shown, the 12 months plan is only partly able to perform and solely by reason of the fact that it is a perpetual calendar.

The Real Question

In sum, reduced to its practical aspect, the 12 months advocates in arguing that their plan will make little difference, not only confess a lack of accomplishment, but more naïvely than this, they demand for their plan alterations in the length of five of the months that *do* cause some difference and then say that since the difference will not be as serious as under the 13 months plan, let us make these lesser changes, notwithstanding that for the purpose of comparing corresponding months they are unnecessary.

The only *valid* reason for disturbing five months is to equalize the already nearly equal quarters; but that can be done by disturbing only two months, and when it is done in either way what benefit do we get? Only the small benefit that can come from the correction of a slight irregularity.

Clearly no alterations in the months are worth while unless they are thereby made equal. The *real question,* therefore, is the expense and inconvenience involved in the adjustment. To attempt to estimate this would be futile, but the fact that several hundred businesses have already made the change can not be ignored. Nor can the fact be ignored that hundreds of others are on record as saying they are ready to make the change at once, if business in general will do likewise. If the cost were thought to be great, naturally the change would not be considered worth while.

Social Convenience

From the standpoint of the everyday use of the 12 months plan for dating events and calculating days and weeks between dates, its perpetual feature does indeed fix week-days to perpetual dates as between corresponding months from year to year; but within the year, *for which the calendar is mostly used,* the improvement over the present calendar is slight. From month to month the week-days change to different dates requiring efforts of memory and calculation little less than at present. Printed calendars would still have to be consulted except by the few with good enough memories to remember the recurring differences among three kinds of months. And without the perpetual feature the 12 months plan would be no improvement whatever as a dating and time-calculating instrument.

In contrast, the 13 equal months plan fixes week-days to the same dates not only as between the same months from year to year but also within the year. Memorizing the dates of one month would suffice for all and the calculation of weeks and days between dates would be simple. And without the perpetual feature, it would still be a considerable improvement over the present calendar; because in any *current* year the week-days would fall on the same dates of each month and there would be no fractions of weeks to confuse the calculations.

Clearly, if we are to stop in calendar reform with the mere equalization of the quarters, the job will have to be done over again some time in the future. Why take two bites at a cherry?

HEALTH COSTS AND THE BUSINESS CYCLE

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THE high cost of medical care has long been a matter of deep concern. Especially is this true since the mass of people have been educated to what might well be termed "health consciousness." The great strides of preventive and curative medicine have paralleled this "health consciousness," and to-day medical care is deemed as essential for one class as it is for another. Provision for medical care is a matter which faces every family, and assumes most serious proportions for the majority of families belonging to the great middle class. It is the purpose of this article to inquire into the movement of medical costs, to determine whether medical costs tend to increase or to decrease during a period when the prices of commodities, wages and salaries in general are subjected to severe deflation, as has occurred during the past few years and, conversely, what is the trend of medical costs in times of a rising general price level, and particularly in an era of active inflation.

PHYSICIANS' FEES

As a rule, specific economic goods and services tend to rise or fall in price in accord with the general price level, assuming that there have been no significant changes in the demand for and the supply of such services or goods. There are, however, certain types of goods and services whose prices are not readily responsive to general economic price movements. In this category are those goods or services which command specific prices fixed by law or by some legal body vested with such power. Rates charged by railroads, telephone companies and other public utilities are of this sort. These are—often belatedly, it is true—usually adjusted by the rate-making body in course of time to the prevailing general price level. Likewise in this category of relatively inflexible prices are those that pertain to certain goods or services for which a customary price is paid. Customary prices are not fixed by government or other deliberate authority; they are the result of long-continued custom and are modified only with great difficulty. Under this classification the fees of the general medical practitioner must be placed.

The prevalent general practitioners' fees in urban communities throughout the United States are $3 per home call and $2 per office visit. These fees have been customary in such communities for years, certainly for more than a decade. If it is assumed that the customary fees were well adjusted so as to afford the average client with medical service at such a price as he could afford, and were adequate enough to provide the average physician with a modest standard of living, it is at once apparent that the maintenance of the same rates to-day represents a price for the same grade of service far in advance of that charged from, say, 1920 to 1929. Since the latter date the price levels of commodities, wages and salaries have declined considerably, as we all know. A family doctor bill of $100 for the year 1928 represented 5 per cent. of a given workman's yearly income of $2,000. To-day, if the workman is fortunate enough to have his job, it is not unlikely that his yearly income is in the neighborhood of $1,500, which would represent a typical 25 per cent. reduction. On the present income basis a family doctor bill of $100, representing exactly the same amount of service as for the year 1928, is equivalent to 6⅔ per cent. of his reduced income.

Measured in terms of wholesale prices for commodities, the medical dollar of the present purchases the same amount of care as it did in 1926, but if employed in the purchase of commodities the purchasing power of the dollar of 1926 is equivalent to $1.639 as of January, 1933, and $1.538 as of June, 1933. As an indication of the actual decline in the spending power of wage-earners, it might be added that in January, 1933, earnings in manufacturing industries were only 35.8 per cent. of the 1926 level, while employment was only 56.6 per cent. of the 1926 level.[1] As of June, 1933, the figures were 43.1 and 62.8 per cent., respectively.[2] However, it was commonly felt in 1926 that medical costs were at that time so high as to be beyond the means of the average workman. If any truth is to be accorded to this assumption, it must be conceded that physicians' fees, remaining nominally the same as five years ago, have in reality reached a level much higher and further beyond the reach of the average working man than was the case five years ago.

What has been said with reference to the fees of the general practitioner applies with even greater force to the much higher fees of the specialist. There is this difference, however. Specialists' fees have never been nearly so uniform as fees for ordinary medical service; they have been adjusted up and down at all times to fit the ability of different clients or of different classes of clients to pay, and in time of depression it is much easier to scale such flexible rates down to any level desired by the specialist. Since such rates are, to a large extent, personal, readjustments may be made at any time without setting a precedent. On the other hand, the customary nominal rates of the general practitioner can not be juggled so readily. A downward revision, say from $3 to $2 for home calls and from $2 to $1 for office calls, would tend to establish a new customary price for such services in the community. There would be no public opposition to a downward revision; in fact, it would be received with public commendation. But once this lower customary rate had been established, it would be doubly hard to institute an increase in rates when the general price level advanced. Any upward revision of a customary price is bound to elicit an undue amount of public antagonism, and cause the beneficiaries to be classified by the populace as racketeers or profiteers, to say the least.

The fact that the family doctor bill for an equivalent amount of service represents a much larger proportion of the average man's income to-day than it did a few years ago may seem to lead to the conclusion that the medical profession is profiting enormously as a result of customary fees. But such is not the case. There is no professional group from which the public seems to expect so much as the general practitioner. In hard times he is expected to be very lenient in the collection of his bills, and naturally he can not be otherwise when his clients are drawn from the poorer and the middle classes, and are suffering from greatly reduced income, either from wage reductions or unemployment, or both. Under such circumstances the average physician finds himself treating many patients who have no means whatsoever, and little likelihood of early employment. In this group many will prove outright charity patients, others will resolve to pay when they have the means, and of these some are prone to forget their obligation as it grows older. The ratio of bad debts has shown a phenomenal increase, especially during the past two or three years. In many urban sections the increase in the proportion of bad debts over that existing prior to the depression amounts to from 200 to 250

[1] *Monthly Labor Review*, March, 1933, Vol. 36, No. 3, pp. 659, 699.

[2] *Ibid.*, August, 1933, Vol. 37, No. 2, p. 411.

per cent. Many doctors have employed an instalment system of collecting their bills, although this method has not proved particularly successful at a time when unemployment is so wide-spread.

We thus see that even with the maintenance of a nominal fee and performance of the same amount of service as in better years, the increase in charity work and in uncollectible bills so reduces the average physician's nominal income that, in spite of the increase in purchasing power of the dollar, his total purchasing power is considerably curtailed. Moreover, there is little likelihood that the average doctor can maintain the normal amount of practise and the same ratio of home visits to office calls to which he was accustomed before the depression period. This is because of the necessity on the part of the majority of people at such a time to curb all unusual expenses, in which class they are wont to place medical expenses. Hence there is increasing reluctance to call a doctor to the home except in cases of extreme illness, and where possible office calls are substituted for home calls. Furthermore, a growing proportion of the public has sought to reduce medical costs by attendance at pay clinics, while others, utterly unable to pay for any medical service, have resorted to free dispensaries and clinics.

The reduction in the number of patients has had the effect of increasing competition within the ranks of medical men, and this in turn has resulted in some places in practises which under ordinary circumstances would be regarded as unethical. Thus there has grown up a certain amount of price cutting, especially by younger doctors who have not yet secured a foothold in their profession and are faced with economic insecurity to a disconcerting degree. Formerly price cutting, where it existed, was done on the sly, whereas to-day it is done quite openly, such doctors advertising the fact that their services are available at clinic rates. Certain clearly unethical practises, which in the parlance of the day might well be called "rackets," have made an appearance or have become more pronounced under the exigency of hard times. In this category might be placed the keen competition for insurance examinations with the hope of inducing the prospective policy-holder to undergo medical treatment not absolutely necessary. Quite often the patient is directed to a cooperating "specialist," who later shares his fees with the doctor from whom the patient was originally sent. He in turn may also play the rôle of "specialist" and receive patients from other doctors under similar arrangements. Compensation cases arising from industrial accidents have in many instances been subject to abuse by requiring the worker to report long after his injury has healed. This is because a certain sum is allowed for each visit of the injured, and stretching the work out as long as possible means added fees.

Dentists' Fees

The situation with reference to dentists' fees is a counterpart of that relating to physicians' fees. However, advertising and price cutting entered this field at an earlier date than in the case of medicine, and has furnished more direct and open competition than has yet appeared in the general medical field. Advertising has become so common in many communities that the old attitude of skepticism and distrust of such dentists has largely given way. This has resulted in a closer relationship between dental fees and the general price level in such communities than exists elsewhere where efforts to maintain customary rates have been successful.

Hospital Costs

To pursue further our inquiry as to the relation between medical costs and industrial depression, let us next glance

at hospital costs. Here again appears the customary price. In the vast majority of hospitals certain fixed rates for the various classes of service are determined upon, usually in accord with the published rates of other institutions prevailing at the time. Once established, these rates tend to become customary; if established during a period of high prices, they are apt to be in conformity to a relatively high price level, and if adopted in a period of low prices the opposite tendency appears. Thus it is not unusual to find noticeable discrepancies in rates nominally asked for a given grade of hospital service by different institutions. Inasmuch as a phenomenal growth of hospital facilities occurred during the decade just passed, it is not surprising that hospital rates for the newer, remodeled or rebuilt institutions tend to reflect the relatively high price levels then prevailing. Moreover, during the period of prosperity the public demand was increasingly in the direction of more exclusive, and therefore more expensive, hospital accommodations, which naturally resulted in attempts to supply such a demand. Furthermore, the growing competition of proprietary hospitals in urban communities no doubt encouraged many private non-profit-making hospitals to add to their more expensive accommodations.

In general, the nominal hospital rates which prevailed in 1928 remain practically unchanged. As in the case of physicians' fees, hospital costs for a given grade and amount of service take a much larger proportion of a man's income to-day than they did in 1928. To those of the great middle class particularly, who have employment and some savings left, hospital costs have relatively increased when consideration is given to lower wages, salaries and to a lower commodity price level.

For a great proportion of the people still above the charity or relief level the effects of the current depression have been so devastating that when hospitalization is needed, cheaper accommodations are now sought. As a consequence the demand for ward, semi-ward and semi-private room service has increased, while the competition of proprietary hospitals for the patronage of those who can still afford to pay for higher priced services, particularly private rooms, remains unabated. This situation has resulted in overtaxing the more moderate priced services, and in many instances in substituting higher priced accommodations which are no longer in great demand for the cheaper accommodations and at the lower price. This is, of course, equivalent to a reduction in price for the better accommodations for those who are the beneficiaries of such a substitution.

The extent of unemployment has increased by a wide margin the number of those who, in need of hospitalization, are unable to pay anything for the service. In metropolitan centers where municipal hospitals are available the demands upon this type of institution have increased greatly, frequently taxing such hospitals beyond their capacity. Likewise the private hospitals which accept charity patients have experienced a cumulative increase in the number of such cases. A sizable proportion of the charity patients of the present time is drawn from the self-supporting working classes, who, during normal times, would revolt at the mere thought of free or even subsidized medical and hospital care.

One of the outstanding consequences of the current depression is the growing conviction that existing or new hospitals should endeavor to provide hospital services for patients of moderate means at such a cost as they can bear.[8] In New York as well as other cities many hospitals are deliberately breaking down

[8] For a full account of this movement see Niles Carpenter, "Hospital Service for Patients of Moderate Means," Publication No. 4, Committee on the Costs of Medical Care.

the former customary rates for hospital service and substituting therefor a flexible scale of rates. Thus charges are based on ability to pay. The incoming patient or his immediate relatives are interviewed by a member of the social service staff of the hospital who thereby obtains sufficient data on the patient's economic status to recommend a fair charge for the individual case under consideration. This practise is applied not only to ward patients, but to those necessitating private or semi-private accommodations. If this custom is more extensively developed, and that seems to be the trend, many of our urban hospitals will have solved the problem of providing facilities for the great middle class, most of whose members, so abhorring the thought of hospitalization in the ward, desire private or semi-private facilities, but do not have the means to pay for such. A practise of this sort would automatically cure some of the evils resulting from customary prices in times of high or low general price levels.

Clinic Fees

With reference to clinic fees little can be said for the simple reason that such charges are generally so small as to represent no great burden upon the average patient either in periods of high or low price levels. Furthermore, it is a common custom in many part-pay or free clinics, where a small fee is asked, to dispense with such payments in needy cases. Pay clinics, on the other hand, which charge the full cost of the service rendered plus a profit for the doctors participating are scarcely more apt to reflect economic changes than customary doctors' fees. It is conceivable, however, that pay clinics representing the cooperative efforts of physicians in providing medical services to their patients at less cost to the physicians may likewise be employed to reduce the cost to patients, and some attempt made to correlate clinic rates or fees to the prevailing level of prices.

Nursing Costs

Nursing is another field in which there has been a tendency toward customary or inflexible rates. This is seen especially with respect to the trained or "private duty" nurse. Efforts to maintain "prosperity wages" for this group under existing conditions have resulted in much unemployment. To quote from the final report of the Committee on the Costs of Medical Care: "The private duty nurse practising individually occupies a position of increasing economic insecurity. So rapid has been the growth in the number of nurses that there are far more private duty and institutional nurses than can be employed under present circumstances. Yet the needs of the people, if fully supplied, would call for all the nurses. The situation is an excellent illustration of the distinction between need and demand. The barrier is primarily, although not exclusively, an economic one."

Other Medical Costs

Many other medical costs illustrate the same inflexible price tendencies which we have already noted. For instance, the price of prescriptions remains about the same year in and year out, showing little apparent relation to manufacturing or wholesale costs of drugs entering therein. It would seem that when the general price level is low the pharmacist values his services more highly, and when the general price level is higher he regards his personal service as of lesser value. It might be said that what the pharmacist loses in purchasing power through selling prescriptions at a stable price, relatively low in times of prosperity, is made up by that same stable price, relatively high in times of depression. Nevertheless, this practise presents just one more instance of a medical cost remaining out of line with respect to general prices, thereby making it more difficult for the consumer to purchase necessary medical attention in times of falling prices. Moreover, the pharmacist in-

variably sells for cash, whereas doctors, nurses and hospitals never collect the full nominal sum for their services because of bad debts and charity work.

The retail prices of "patent" medicines and nostrums, on the other hand, are more apt to reflect general price changes than are prescriptions. This is especially true since the advent of the chain drug store, the department store and the mail order house. Widely advertised proprietary medicines afford an excellent drawing card when deeply cut prices are advertised, and this, no doubt, encourages a certain amount of self-medication, a practise which is scarcely to be approved. In this field alone, then, do certain medical costs seem to follow the general trend of prices.

Conclusions

In no field of modern business nor in any of the professions is there to be found the relative fixity of charges which persists in medical and allied health work. In industry wages, salaries and commodities are extremely sensitive to fluctuations in the supply of or demand for labor or goods. Prices of individual commodities or services, barring unusual changes in the particular supply or demand, tend to conform to the rise or fall of the general price level. A striking exception, however, is found in the various branches of medical and health work. Here customary fees or charges, once adopted, show tremendous resistance to change. This phenomenon has a decided influence upon the ability of the poorer, and even the middle economic groups of our population, to purchase necessary medical attention. In periods of depression medical care becomes relatively more expensive, although remaining absolutely the same in dollars and cents. The consequences are deferment of medical care if the individual's health is not in a precarious state, resort to cheaper health agencies, such as office calls at the physician's office instead of home calls, a shift in demand from more expensive and exclusive hospital accommodations to those of a less costly grade, and greater use of part-pay and free clinics. Frequently the patient of limited means seeks quick and cheap relief by the use of patent medicines or other nostrums, and also at the hands of quack doctors who do not hesitate to advertise their low rates and cure-all methods, while in more prosperous times little thought would have been given to these questionable agencies.

No gains are experienced by the medical profession, hospitals or other legitimate health agencies through the strict maintenance of customary fees or charges. Considerable practise is lost to the ordinary practitioner, price-cutting tends to make its appearance here and there, and fee-splitting and other unethical practises become more or less general. Much work is performed by the general practitioner for which immediate or early payment is impossible. Customary fees in a time of depression cause the doctor's bill to appear overwhelming and unreasonable, and as a consequence many of such bills become uncollectible since the outraged debtors refuse to make any efforts at payment. Moreover, the amount of free work is greatly increased. Hospitals, as well as other health agencies, find themselves in a similar plight.

Medical and health agencies and individuals engaged in such work are powerless to overcome the wide fluctuations of the business cycle. The causes are, of course, industrial in nature, and the more important adjustments must be made in that field through stabilization of the price level, banking reform, industrial planning and the like. But within the medical field an abandonment of customary fees and charges would seem to be an apt adjustment. The consuming public, especially the self-supporting working class groups, would be enabled to purchase medical care at a

cost within reach, and physicians, nurses, hospitals and other agencies would receive more in a period of depression by charging lower nominal rates for services than they would through the maintenance of customary fees because of the very fact that at such a time they simply can not obtain the income the customary rates seem to demand.

On the other hand, physicians, nurses, hospitals and clinics would benefit greatly without the incubus of customary price in a period of prosperity. Then medical costs could be raised in keeping with the rise in the general price level. As a consequence the public would be in a position to expend a relatively stable proportion of its income for medicine, both curative and preventive. As a means of maintaining a certain degree of uniformity in physicians' fees within an area, local medical societies could easily publish approved standard rates from time to time, say every three to six months, which would thereby keep medical costs in alignment with the prevailing general price level. A similar plan might also be worked out with reference to dentists' fees, and even the rates for nursing service might be made amenable to such a scheme. This suggested program would naturally require a certain amount of publicity, and assurance that adjustments in rates, especially increases, were not arbitrary for the purpose of fleecing the public, but were made in accord with a well-known price index as a means of making physicians', dentists' and other medical fees reasonable at all times. As for hospitals, a similar arrangement would seem quite feasible, assuming a desire to maintain a rate schedule for the various grades of service offered. The end in view, however, is already being accomplished to some extent by the application of flexible rates in many institutions.

It has recently been pointed out that socialized medicine by means of group practise and group payment will bring the cost of medical care down within the reach of the vast majority of people. There is no certainty that this will result, for, in fact, if customary group fees, even though paid in a fixed sum monthly, quarterly or annually, become the rule, the same difficulties are bound to ensue as are now found in competitive medicine. Moreover, should medicine be so completely socialized as to become a state function physicians would find themselves on a fixed salary basis, probably with little or no distinction between the good or the bad, the competent and the incompetent, and would be subject to all the vicissitudes of changing price levels without the slightest means of adjustment. This difficulty would be felt most in times of prosperity accompanied by a rising price level. From the standpoint of the public, in the case of state medicine, the costs would be disguised in the form of taxes, and the entire burden would be shifted to certain groups of taxpayers, although many of the beneficiaries, not possessing taxable property or resources, and yet able to bear ordinary medical expenses, would be exempt from all costs.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE POPULATION PROSPECT

By Dr. O. E. BAKER

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I SHOULD like, if I may, to consider with you the effect of the change, particularly noticeable since the world war, in the desires and ideals of the young people—their decisions as to what is worth while—upon the prospect for population growth in the United States. We are approaching the time when children will be born, with few exceptions, to those parents only who want them. What does this mean in terms of national development and destiny?

For twelve years the number of births in the United States has been less each year than in the year preceding, with three exceptions. In 1933 nearly 700,000 fewer children were born than in 1921. In addition, the flow of immigrants from Europe has been stopped; indeed, each year during the last three years more people have left the United States than have entered it. Ten to twelve years ago the yearly increase of population in the nation was about 2,000,000. Now it is less than 1,000,000. In 1933 it was, apparently, a little less than 800,000. The enrolment in the lower grades of the schools has started downward and will soon decline rapidly.

Moreover, there is no sign that the decline in the birth rate is slowing up. And already there are not enough children being born to maintain the present population permanently. However, the population of the nation will continue to increase for at least five years, probably fifteen years, possibly twenty years, principally because of the large number of middle-aged people, the heritage of a higher birth rate and heavier immigration in the past. As these middle-aged people grow old and die the death rate will rise, not because people are dying younger, but because there will be more and more old people to die. The census of 1930 showed that people over 65 years of age had increased 34 per cent. since 1920 in the nation as a whole and 50 per cent. in the cities. The census of 1940 will show a similar increase of old people, and by 1950 there will be nearly twice as many old people in the nation as in 1930.

Slowly the number of deaths will increase, while the number of births seems likely to decrease for some time to come. Probably 10 to 20 years hence births and deaths will balance. This balance may last for a few years, resulting in a stationary population. Afterward deaths will exceed births, unless the birth rate rises or the restrictions on immigration are relaxed. When this occurs the population of the nation will begin to decline. According to estimates of Thompson and Whelpton, of the Scripps Foundation for Research in Population Problems, at Miami University, Ohio, the population of the United States in 1940 will be about 132,000,000. By 1950 the population will have increased to 136,000,000. In 1960 the population will be about the same as in 1950, the peak having been reached between these years. By 1970, according to this estimate (which is only one of several these statisticians offer,

but the one I prefer) the population of the nation will have declined to about 132,000,000, and by 1980 to 126,000,000, which is about the same population as at present.

This estimate was made more than a year ago. The continued rapid decrease in births in 1933—more than 100,000 fewer, apparently, than in 1932—suggest that the stationary population may be nearer than even this "low" estimate of Thompson and Whelpton indicated. If the increase in the nation's population continues to diminish at the same rate as during the last ten years, the population of the nation will be stationary about 1942.

We have probably 15 years ahead of us before the peak of population is reached, and 30 years before the decline from this peak will have reached the present population level. There is time in which to develop a new attitude toward children and family responsibilities, and change our manner of living so that children will not cost so much to raise and educate as at present. Dr. Dublin, statistician of the Metropolitan Life Insurance Company, estimated prior to the depression that the average cost of raising a child to the age of 18 in New York City was about $7,500, or fully $10,000, if 5 per cent. interest on the investment be allowed. Three children per mother, the number necessary to maintain population stationary, mean, therefore, an investment of $22,000 to $30,000. The average cost on the farms is probably only a third as large, and in the small towns and villages is intermediate. The decline in the birth rate would, doubtless, be retarded if a larger proportion of the people lived in suburbs, small cities and villages, particularly if many engaged in part-time farming.

According to the census of 1930, the number of children under 5 years of age in the large cities lacked about 20 per cent. of being sufficient to maintain a stationary population permanently, without migration from rural areas or immigration from foreign lands, while in the smaller cities there was about 6 per cent. deficit. On the other hand, in the village and suburban population there was a surplus of children of fully 30 per cent. and in the farm population a surplus of 50 per cent. above the number necessary to maintain that population stationary. In 1930 urban deficit and rural surplus about balanced, according to Dr. Lotka, of the Metropolitan Life Insurance Company, but since 1930 the national birth rate has declined 12 per cent. further. The rural population is no longer able to maintain its own numbers and provide enough young people for the cities, even if jobs could be found for them, to balance the urban deficit. The large cities particularly may well consider the handwriting on the wall. We may be on the verge of great shifts in the residence of the people.

Fully as important, I believe, as an increase in the proportion of the population living in a rural environment is an increase in the number of parents who are willing to sacrifice for the sake of children and the preservation of the family line. In my opinion, the accelerated decline in the birth rate which followed the world war was owing not only to the high cost of living, particularly in the cities, but also to the disillusionment of many young people after the war and to changes in their desires and ideals. The craving for luxury, amusements and social position apparently became keener than before, and the striving for a higher standard of living became more wide-spread. In many, perhaps in most, cases this higher standard of living could be achieved only by a rigid restriction on the size of the family; as a hard-working, married student in a university, who had two chil-

dren, remarked to me several years ago: "No more babies until we have an automobile."

This rapid decline in the birth rate is as wide as the European sphere of civilization. A stationary population in Great Britain, France, Germany and the Scandinavian countries will be reached, it is now estimated, within ten years, and a few years later decline will set in. It appears that our modern urban economic system, with its associated social ideals, tends to reduce the birth rate below the level of population maintenance as universally as the former self-sufficing agricultural system tended to maintain it above that level. In every state of the United States, without exception, the ratio of children under 5 years old to women of child-bearing age is smaller in the urban population than in the rural; and this is true also of every nation of Europe that collects birth statistics, likewise of Canada, Australia, New Zealand and Japan. The social code, if such it may be called, which is characteristic of the people in the cities particularly, is unquestionably promoting depopulation. And it seems unlikely that this code will be changed in time to prevent a declining population in the United States and the nations of northwestern Europe.

After the decline sets in there may develop a movement of religious intensity directed toward the preservation of the family, the nation and the race. To be a parent of healthy children may afford as much social prestige as to be the owner of a high-priced automobile or of over-stuffed furniture. It is possible that this change in ideals and in estimates of things worth while may develop before the decline in population actually sets in. Let us hope so, for a declining population will have very serious economic, psychological and biological consequences.

THE HYGIENE OF HAY-FEVER

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"DEATH, taxation and hay-fever are inescapable." This is the cry of resignation of 2 per cent. of our population. Hay-fever was first described as a disease entity by physicians of the old English school. The view that hay-fever is caused by the pollens of flowering plants has now met with universal acceptance. However, the disease is one of greater concern to the American public. Approximately 70 per cent. of hay-fever victims in this country owe their distress to the pollens of the ragweeds. Curiously enough, the geographical distribution of the ragweeds is restricted to the North American continent. The blooming period of these weeds extends from the middle of August until the advent of frost. This period embraces the fall or autumnal variety of hay-fever, in contradistinction to the spring and summer types of the disease. The spring type is due to the pollens of the trees, whereas the summer type is caused by the pollens of the grasses or of the plantains.

Two months hence, the vast army of sufferers will begin to experience their "annual torment," to use the phrase of an English physician, and sneezes will resound throughout the length and breadth of our land. Recurring popular appeals to exterminate the ragweeds accompany the symptoms of distress. Ob-

viously, the attempt to annihilate any species of plant or animal life is attended with unsurmountable obstacles. It constitutes primarily a defiance of the laws of creation.

Of all the diseases to which human flesh is heir, hay-fever enjoys an unusual distinction. It is regarded as the most serious of non-fatal maladies. Its symptoms have been made the subject of jest. "Hay-fever" is even the title of a comedy-drama. Fits of sneezing, a copious discharge from the nose and eyes, stuffiness of nose, intolerable itching of the lining membranes of the nose, eyes, mouth, throat and ear canals, and occasional attacks of asthma furnish evidence of the irritating qualities of the pollen grains upon the tissues of susceptible persons. These local manifestations are only too well recognized by the members of the family circle to which the victim belongs. In this instance, at least, familiarity breeds sympathy. Nevertheless, one of the most apparent complications of hay-fever is a defective heat-regulating mechanism. This condition was tersely described by a patient when he bewailed the fact that his thermostat was out of order. The disturbance of the heat-regulating mechanism of the body is an integral part of the disease which has failed to receive the attention it merits. The authoritative works, which have enriched our literature of the past decade, fail to emphasize this important constitutional derangement. It occurs during, and in some cases extends beyond the seasonal upheaval. Now, there is a school of economists which attributes the present economic ills to the mechanized age. The coincidence is, indeed, a strange one, that this mechanized age has also conspired to provoke and aggravate the distress of hay-fever patients.

The maintenance of the body temperature and the conservation of body heat are two of the most vital functions of the human body. Their successful accomplishment depends upon a delicately coordinated mechanism—such as the nerve fibers in the skin and in the walls of blood vessels which convey impulses to and from the spinal cord. These impulses are in turn conveyed from the spinal cord to the heat-regulating center in the brain which acts as the thermostat, so to speak. Under normal conditions, body temperature is maintained at a fairly constant level because heat production and heat loss are equal, and because any change in either process brings about a compensating change in the other.

The term "hay-fever" is a paradox. It is a non-febrile disease. Nevertheless, hay-fever victims do feel hot and feverish. The skin is usually warm because of the dilatation of the blood vessels therein. More blood is brought to the surface from which heat is dissipated. This condition is not unlike that seen in alcoholic intoxication and explains the blush and the flush of inebriety. The dilatation of the blood vessels results from a disturbance or poisoning of the nerve fibers which control the caliber of blood vessels. Pollen disease with resulting poisoning from the absorption of the soluble pollen material is a more accurate designation than hay-fever.

When cold air strikes the skin, there is an immediate loss of heat. The warmer body radiates its heat to the colder environment. One of nature's inexorable laws is the conservation of body heat. This is effected by the contraction or shutting down of the blood vessels in the skin—a mechanism which is quite analogous to shutting off the heat from a radiator by closing the valve. A diminished volume of blood now courses through the skin, whereas the excess of blood finds its way in part into the mucous membrane of the nose. Herein are

located the so-called turbinate tissues or "swell bodies," which act very much like the ordinary sponge. Their volume varies with the volume of contained fluid. The engorgement of the turbinate bodies causes the familiar sniffing, and the consequent pressure upon the nerve endings in the nasal mucous membrane gives rise to sneezing. This is a common experience. The congestion of the "swell bodies," irrespective of cause, is indicated by sneezing, fulness of the nose and nasal discharge. These reactions of the nasal tissues are more marked in the case of hay-fever subjects due to impairment of nerve functions. Therefore, the effects and symptoms are more lasting than in the normal person.

Let us now consider the innovations which tend to bring about a dissipation of body heat. The automobile ranks first in importance to the hay-fever patient. When horse-power furnished the sole means of transportation twelve to twenty miles per day of travel was a reasonable expectation. That same distance can now be covered by motor car in one-half hour or less. With windshield up and windows down the automobilist is transported through space at a faster rate than ever before in the history of man. The faster the rate of travel, the faster does body heat radiate to the quick onrush of air. The passengers, attired in light summer garb, are denied the protection of adequate clothing against such a rapid loss. At journey's end, the hay-fever victim finds that disease and discomfort have displaced relative ease and comfort. Moreover, a ride in the rumble-seat is anything but a joy-ride. The wet eyes and the wet nose tell their own story.

In the new design for automobiles, the no-draft ventilation seemingly atones for the all-draft ventilation of the rumble seat. "Do not travel during the hay-fever season" is a slogan worthy of adoption by all victims of the disease. It is difficult to explain the reasons which prompt the hay-fever subject to plan automobile tours during the season of his greatest disability. If a tour of the country is to form part of a recreational program, it should be arranged for those months when the hay-fever victim is free from symptoms. Then and only then will a vacation prove symptomless.

Engorgement of the nasal tissues, with the train of symptoms previously described, likewise results when the air is agitated around and about the individual in a quiescent state. The electric fan, another contribution of the mechanistic age, may similarly produce the dire effects in rotation. It is particularly noteworthy that the rate of air-speed in the case of the more powerful electric fans varies from 6.8 to 19.3 miles per hour. The reports of hay-fever subjects who are unwillingly and unwittingly exposed to the direct currents of air of electric fans indicate that their symptoms are either provoked or intensified. The reasons are only too obvious. Under normal conditions a person who anticipates exposure to gusts of air, with a velocity of nineteen miles per hour, will protect himself with a light outer garment. In the office and shop, during the season when fans are in active operation, a minimal amount of clothing consistent with modesty affords no barrier to the rapid loss of body heat.

Some thoughtless persons engage in a practise which is especially fraught with danger. They permit an electric fan to blow directly upon them while asleep. It will be recalled that hay-fever patients, because of their unstable heat-regulating mechanism, tend to lose body heat. Moreover, during sleep, even in the normal individual, the temperature falls because of bodily inactivity. The vessels of the skin are usually dilated,

owing to the diminished control exercised by the dormant nerve centers. When, in addition, the electric fan incites a still greater dissipation of body heat, the awakening is indeed sad. In the early morning hours the hay-fever subject is likely to be aroused out of his sleep by vigorous blasts of his own creation. Mothers and nurses will do well to heed this warning. The direct exposure of sleeping babies and children to the currents of air of electric fans is an act which can not be condoned by any humane consideration.

The movie industry has, also, moved many a hay-fever victim to tears and sniffles. This industry has pioneered in making indoor amusements attractive to the populace during the hot weather season. To accomplish this purpose, the artificial cooling of theaters has become an important adjunct. The patron of the arts, warm of body and with undergarments saturated with perspiration, enters the air-cooled auditorium. Eventually he is seated in the huge refrigerator. He is in cold-storage for at least two hours. His reaction to the new environment is determined by the difference between the indoor and outdoor temperatures. A difference of ten to twelve degrees may serve to add comfort to the enjoyment of the show. However, the differences are usually greater. The subjection of the human body, especially when thinly clad, to such a sudden fall of external temperature causes a rapid dissipation of body heat. The normal individual readily accommodates himself to the changed conditions. His heat-regulating mechanism functions adequately. The hay-fever patient soon experiences the stuffiness of nose and paroxysms of sneezing. The inevitable result of an evening intended for pleasure is the intensification of symptoms for twenty-four hours or even longer.

The extension of the use of air-cooling devices on trains and in office buildings is fraught with similar peril for the hay-fever victim. To compensate in part for the loss of body heat, it follows that one should bestir himself into some form of muscular activity. This obviously is impossible in the air-cooled train or theater. The hay-fever subject restrains every motion excepting the commotion of pent-up sneezes.

Dress, dictated by fashion, has now approached the vanishing point. "Back to Nature" may be fitting for members of the Nudist cult, but it is distinctly unsafe for young hay-fever victims. The physiological purpose of clothing is to conserve body heat. Young children, attired in the conventional sun-suit, expose a vast expanse of body surface to the fluctuations of the external temperature. In case of children who are hay-fever or asthmatic victims, the loss of body heat is attended by a flare-up of their distress.

The American people displays its national temperament in its policy of keeping cool in the hour of trial. The hay-fever victim, however, should, in the interest of comfort, harken to the dictate of hygiene: "Keep warm inside and outside."

THE MYSTERY OF THE OCEAN

By Dr. PAUL S. GALTSOFF
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SINCE the earliest days of our civilization the great blue expanse of the ocean has had a mysterious appeal to our imagination. To the inquiring mind of a man of the ancient days the circular disk of his small inhabitable world

seemed to be surrounded by a mighty stream of water which, he believed, was the abode of many fearsome monsters, strange human-like creatures and freaks. This conception, originated by the Chaldeans and Egyptians, was handed down from generation to generation. It was generally accepted in the time of Homer by Greek geographers who called the ever-running river the Oceanus, the name of a primeval god.

The beginning of the science of oceanography dates back to the year 1522, when one of the vessels of Ferdinand Magellan returned to Spain after having for a first time circumnavigated the globe. In 1768 Captain J. Cook, sailing in the *Endeavor,* started on the scientific expedition during which he made the first deep-sea soundings, observed the temperature of the water and collected numerous astronomical and biological data. From this time onward hundreds of expeditions organized by every civilized country have explored the ocean.

Most ingenious instruments and implements were invented for catching various organisms of the sea, ranging in size from the smallest microbe of less than one thousandth of an inch to the largest living mammals, like the blue whale, which reaches the immense length of 85 feet or more and weighs over 300 tons. Fantastic tales about the life in the ocean were gradually replaced by accurate knowledge. Sea monsters and other creatures collected by the expeditions were meticulously examined by scientists and were described and classified. They were carefully preserved in alcohol and placed on shelves and in cases in our great museums.

It is true that with the advance of scientific knowledge the romance and adventure of the old days associated with the great oceanic expeditions have been lost, yet life in the ocean still remains veiled in mystery, and the biologist of to-day, starting on a new exploration, may be as much thrilled as were the pioneers of science who sailed with Magellan and Cook. His principal aims, however, are different. He is more interested at present in determining the laws that control life in the ocean and in unraveling the intricate relationships which exist between the denizens of the sea and their environment, rather than in finding and describing new forms of life.

Perhaps the greatest secret of the ocean lies in its very essence, the sea water. The layman may be amazed to learn that such a common thing as sea water may still be an object of scientific research. Yet our present knowledge of the composition of the sea water is very incomplete. Earlier analyses established that sea water contains about 3½ per cent. of salts, of which over three fourths consist of common cooking salt or sodium chloride, the remainder being made up of small quantities of Epsom salt, gypsum, calcium and others.

Modern analyses reveal its much greater complexity. Out of 80 known elements at least 32 enter into a composition of sea water. Many of them occur in such small quantities that their presence can be revealed only by the spectrographic analysis, and in some cases must be assumed because they are found in the bodies of marine animals and plants. For a long time there was a tendency on the part of the chemist to disregard the importance of substances which are found in the sea water in minute amounts, but recent discoveries in the physiology of nutrition taught us to pay more respect to them. We know, for instance, that iron, copper, manganese and iodine are necessary for the normal functioning of our bodies. Undoubtedly they are indispensable for the reproduction and growth of many marine forms, yet they occur in the sea water in concentrations of only a fraction of a part per million.

Traces of silver and gold were also found in the sea water. It has been estimated that there exist dissolved in the sea 13,300 million tons of silver, or 46,700 times as much as had been mined all over the world between the discovery of America and 1902. The presence of gold floating in the sea and ready to be taken by any one who can do it attracted a great deal of attention. According to the old analyses, each ton of water contained 5 milligrams or one twelfth of a grain of gold. Soon after the war, when Germany found herself desperately in need of gold, the German chemist Fritz Haber attempted to extract it. He found, however, that the actual gold content in sea water was only one one-thousandth of what was previously estimated. Since the cost of extraction would be greater than the value of the recovered metal, the hope of amassing great fortunes out of sea water quickly died out. Although gold recovery failed, the extraction of bromine, an element very valuable to industry, the recovery of which was regarded for a long time as a fantastic dream, is now being developed on a commercial scale, and a first plant is being erected near Wilmington, N. C.

While attempts of the chemists and engineers have been balked by many technical difficulties the problem of extracting various elements from sea water has been successfully solved by the marine organisms. Chemical analyses reveal the interesting fact that certain elements, which are found in the sea only as traces, as, for instance, iron, copper, zinc, iodine, vanadium, barium and boron, are accumulated and stored in the bodies of fishes, mollusks, shrimp and other animals and plants.

The accumulation of iodine is probably of greatest interest and importance. Although it is found in the sea in a concentration of about three tenths of a part per billion, large quantities of it are accumulated by algae, mollusks, crustaceans and sponges. Among the edible fish and shellfish the highest iodine content was found in lobster, which contains 11.6 parts per million, and in our oyster, which contains 6 parts per million. It is generally accepted that the deficiency of iodine in our food is the cause of goiter and that the disease can be prevented by including in our diet food that is rich in this element. In certain algae and sponges the iodine accumulates in such large quantities that it can be extracted for industrial purposes. A very common red sponge, *Microciona,* which abounds on oyster beds, contains more than 5 per cent. of iodine (dry basis).

Many other elements are extracted from sea water and stored in the bodies of living organisms. Calcium, magnesium and phosphorus are used by fishes, mollusks, coelenterates and others for the construction of bones, shells and skeletons. Many sponges use silica for building up a network of thin needles which support their bodies. Unicellular Radiolaria select strontium, of which they construct their beautiful skeletons. Sac-like sedentary ascidia accumulate vanadium and use it in the same manner as iron is used in the blood of warm-blooded animals. There are many instances, however, when the purpose of accumulation of the material and the use made of it by the organism are unknown. Thus, we are unable at present to explain why oysters and clams store about 10,000 times as much zinc and more than 1,000 times as much copper as is present in sea water. We do not know why lobsters and sponges need iodine, which they accumulate in their bodies.

In the light of modern science the ocean appears to us as a huge chemical laboratory in which the work goes on continuously without interruption; and the chemical activities of its inhabitants seem to be as diversified as their appear-

ance and structure. Different elements are withdrawn from water, temporarily stored in the bodies of living forms and after their death are deposited on the bottom and redissolved. It has been estimated, for instance, that due to the activity of living forms about 1,400 million tons of lime are being deposited annually on the bottom of the sea. A study of the chemistry of the ocean shows that the turnover of various elements is intimately related to the organic life in the sea and that the life cycles of various forms constitute only brief links in these chemical changes.

To many marine organisms the sea water is not only a medium in which they live but is the essential constituent of their bodies. Suffice to mention the forms, like the jellyfish, which contain more than 90 per cent. of water. Many organisms, like the sponges and coelenterates, are continuously forcing a stream of water to go through their bodies, providing themselves in this manner with food and oxygen for respiration. In these forms sea water plays a rôle of blood in higher animals.

Biologists have accumulated sufficient evidence to maintain that life began in the ocean and that fresh-water and land animals developed from marine forms. In this connection it is interesting to mention that the blood of higher forms, including man, contains the same mineral salts that are found in the sea. It is probably fortunate that scientific research in solving the old mysteries of nature has opened up new fields of investigation and encountered new secrets. Maybe the day will come when the key to the solution of the greatest mystery, the origin of our life, will be found in the depths of the ocean.

THE LIZARD-EATING SPIDERS OF BENGAL

By GOPAL CHANDRA BHATTACHARYA

BOSE RESEARCH INSTITUTE, CALCUTTA

THAT some spiders feed on vertebrates is no longer contestable. Accounts of different vertebrates, such as fish, rats, snakes, frogs, lizards, etc., being captured by different species of spiders in different parts of the world have been recorded. Dr. Ernest Warren[1] describes his observations on certain lizard-eating spiders, *Palystes natalius*, as follows:

> At the beginning of July, 1923, Mr. W. G. Rump, caretaker of the Natal Museum, has noticed on a sunny morning at about 10 A. M. in a garden in Pietermaritzburg two large spiders on the woodwork of a fence, at a height of about 4 feet above the ground. The two spiders, with a leg span when walking of about 3 inches, were seen close together clinging to some large dark object. One spider was killed, while the other escaped, and the object to which both spiders had been attached proved to be the body of a recently killed lizard, *Lygodactylus capensis* (A. Smith) which, when straightened out, was about 2¾ inches in length. . . . Subsequent experiences render it probable that the lizard had been killed by the spider or spiders, less than an hour previously.

A series of interesting accounts of fish and lizard-eating spiders has been collected by Dr. Gudger[2] and contributed to the *Natural History Magazine*, New York. From a private communication from him I understand that he has some more material on the subject in hand. Captain Thomas Hutton[3] refers to Galeodes (vorax?) as the lizard-eating spider of Mirzapore, Bhowalpur and Afghanistan. He says "A lizard three inches long, exclusive of tail, was entirely devoured; the *spider* sprung at it, and made a seizure immediately behind the shoulder, never quitting its hold until the whole was consumed." But Galeodes are not considered to be real spiders. They represent something between scorpions and spiders.

No instance of true lizard-eating spiders from India and especially from Bengal has so far been recorded. Recently, however, while experimenting with spiders for finding out the location of their auditory organs and determining if parthenogenesis really takes place in them, I have come across a species of these lizard-eating spiders, *viz.*, *Argiope pulchella* Thor., of the family of Argiopidae found in Bengal. These Argiopidae were found suitable for the above experiments, and I reared a number of young Argiope in several small rooms. Some of these spiders were provided with frameworks of wood, specially made for the purpose of constructing their webs, while others were allowed to make their snares anywhere at random. After closing the glass windows, live specimens of dragon-flies, moths, butterflies, etc., were from time to time let loose in these experimental rooms, in one of which a spider of the size of about 3 inches from foot to foot built a web measuring no less than 3 feet square. On May 8, 1933, I saw a medium-sized dragon-fly (*Crocothemis servilia* Drury) caught in a corner of the web. The fly, having stuck in the glutinous thread of the web, flapped its wings vigorously to set itself free, at which the spider, which was resting quietly on the X-shaped flossy ribbon at the center of the web, got frightened and ran off to one

[1] Ernest Warren, D.Sc., "Notes on a Lizard-Eating S. African Spider," *Annals Natal Museum*, Vol. 5, Part I, p. 95, 1923.

[2] E. W. Gudger, "Spiders as Fishermen and Hunters," *Nat. Hist. Mag.*, Vol. xxv, No. 3, pp. 266–275, May–June, 1925.

[3] Captain Thomas Hutton on Galeodes (vorax?), *Jour. Asiatic Soc.*, Bengal, Vol. xi, Part II, p. 860. July–Dec., 1842.

extreme corner. After half an hour or so I was surprised to see a moderately big lizard sticking to the web near the fly and struggling to get out of it. A wide rent had been made in the web, evidently by the struggling lizard, which by then was dangling with its head and feet stuck in the glutinous thread of the web, the broken threads in their turn having entwined the hinder part of its body. The flapping of the wings of the fly must have attracted the lizard to the death trap. As soon as I drew near, the latter made a violent effort to set itself free but all in vain, so effectively was it snared that only the opening of the rent grew wider. I retired to a suitable distance and awaited further developments. After a few minutes' struggle the lizard became exhausted and motionless. All the while the spider was seen clinging to the ceiling of the room and was, as it were, quite indifferent to the disturbances that were going on in its web. Fifteen to twenty minutes elapsed in suspense, when the lizard made another violent effort to free itself from the snare. Instantly the spider came down and tore off a radial line so that a large portion of the web was loosely thrown over the struggling victim. The spider silently watched for a minute or two and then suddenly springing upon the lizard swathed it by a stream of flossy ribbonlike threads with the help of its hindmost legs. The body of the victim being larger and heavier than that of its own, the spider could not revolve the lizard bodily for a perfect swathing, but only threw streams of flossy silk over the captive. At this moment the lizard, thus entangled, made a final and desperate attempt to free itself. This time at least fortune smiled on the poor creature, and it escaped carrying along with its tail a portion of the web. The perplexed spider, being denied the dainty meal, retired to the

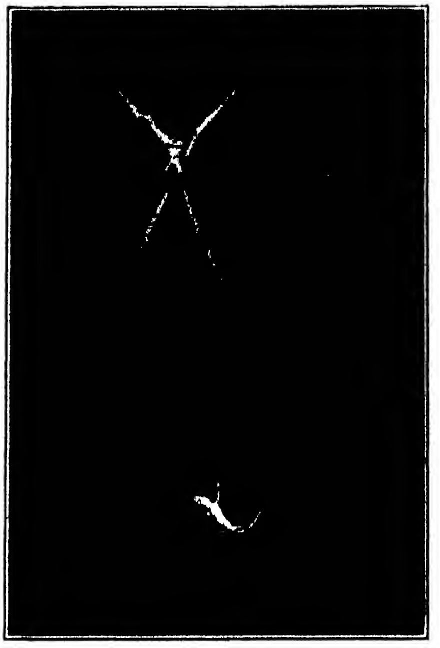


FIG. 2. THE LIZARD IS SEEN STUCK IN THE WEB AND THE SPIDER AT THE CENTER

FIG. 1. THE SPIDER IS SITTING AT THE CENTRAL CROSS OF THE WEB

FIG. 3. THE TRUSSED-UP LIZARD IS SEEN ATTACHED TO THE WEB

central cross and began to toilet its head and feet.

Being encouraged by this incident, I placed the same spider on a wooden frame in order that it might construct a fresh web therein. By the evening the spider had actually built up a large beautiful web inside the frame and was quietly sitting at the central cross (Fig. 1). The frame with the spider was then removed to a lumber room full of common house lizards, *Hemidactylus coctaei*. A simple device was made by means of a wooden elbow-bend to entice the lizards to the web. One arm of this elbow-bend was attached to the ceiling of the room, the free end of the other arm being placed very close to the vertical plane of the spider's web. On the other side of the web, just opposite the free end of the arm, was placed a stand, on the top of which a living dragon-fly was mounted. The gap between the fly and the free end was hardly more than an inch, the web occupying the intervening space. The idea was that the flapping of the wings of the fly would attract the lizards and cause them to climb down the elbow-bend and spring upon the fly. Though the device was complete I had to wait a couple of days before anything actually came to pass. I replaced a fresh and vigorous fly every day, as I had noticed one or two lizards going back from the elbow-bend, owing to the weak fly having stopped moving its wings. Then on May 26, 1933, at about 3 P. M. in the afternoon I noticed a lizard actually stuck in the web in its attempt to capture the dragon-fly. The lizard measured about 3¾ inches in length from head to tail. Under the weight of its body a big rent was made in the web, in which the lizard itself got entangled and was hanging loosely. It made a vigorous attempt to set itself free from the snare, but in vain. After a few minutes' struggle it remained motionless for a considerable time, when a photograph was taken (Fig. 2), the spider in the meantime having returned to its original position. Half an hour passed quietly, when the lizard began to strug-

FIG. 4. THE SPIDER IS SUCKING THE JUICE OF A CRUMPLED BIT OF FLESH OF THE LIZARD

gle again. All the time the spider was getting ready to attack the victim, and no sooner did the lizard begin to move than it sprang upon the latter and began to throw flossy streams of ribbon all over its body. The struggling of the lizard continued, but the spider did not stop throwing flossy silk until it was completely mummified. The spider then firmly attached the trussed-up victim to the web and took a drag-line to the central cross where it fixed the other end of the line. It then displayed a peculiar dancing attitude by raising its body upon its legs for three or four times, which is the usual practise with all the spiders of this species, in order, as it were, to express its joy and excitement at the success just attained.

The spider kept quiet for some time and then mended a portion of the upper part of the torn web and partially rebuilt the cross at the center. The lizard was still alive, the shivering of its body being distinctly visible through the translucent silken threads. Fig. 3 shows the trussed-up lizard and the position of the spider on the web. At about 6 P. M. that very evening the spider crawled to the trussed-up victim and inserted its fangs into the neck of the lizard. Inside the silken sheath, the lizard, which was still alive, shivered twice or thrice and was silent forever. The spider remained biting for a few minutes and afterwards dragged the swathed victim to the center of the web, where it began chewing the latter to pulp. Next morning by 11 A. M. only a crumpled bit of flesh and skin was left and it could by no means be recognized as the remains of the lizard (Fig. 4). The photograph shows the spider busy chewing the crumpled bit. By a quarter past twelve the spider stopped eating and dropped the remnants to the floor. On examining the crumpled black mass a portion of a lacerated skin and smashed head, with traces of broken pieces of bones, could be recognized. The spider, with its abdomen now greatly distended after the repast, remained sluggish for the next five or six days, during which time it refrained from taking any more food. It did not even care to mend the web or make a new one. A few days later, however, the same spider captured another young lizard in a freshly constructed web and devoured it in the same manner as detailed above.

The observation just recorded is not a stray or accidental one. I have, under similar circumstances, observed exactly similar behavior on the part of other specimens of the same spider.

D. MENDELÉEFF

THE PROGRESS OF SCIENCE

THE CENTENARY OF A SCIENTIFIC PROPHET—DMITRI MENDELÉEFF

ALL over the world, wherever lectures in chemistry are given, and nowadays in most physics lecture rooms there is found a table or chart listing and classifying the elements. This table usually bears the name of Mendeléeff, who was its inspired originator. Many readers may recall that this "Periodic System of the Elements" is prominently displayed at the Chicago Century of Progress Exposition.

In September of this year Russia celebrates with a series of scientific gatherings in Leningrad and Moscow the centenary of the birth of one of its greatest men of science, Dmitri Ivanovitsch Mendeléeff.

Mendeléeff was born in Siberia of good intellectual and pioneer stock. The last and seventeenth child, he was dedicated by his mother to the pursuit of higher learning. Dogged by family .misfortunes, illnesses and poverty, he was only just able to gain admittance to a college in St. Petersburg which provided him with all material necessities and brought him into contact with a number of recognized scholars. Years later he was permitted by the Minister of Public Instruction to study abroad in Paris and in Heidelberg. Shortly after his return he became professor of chemistry at the Technological Institute, and in 1869, at the age of thirty-two, professor at the University of St. Petersburg.

In March, 1869, Mendeléeff presented to the Russian Chemical Society his immortal paper, "On the Relation of the Properties to the Atomic Weights of the Elements." This was a remarkable generalization which covered all the 63 elements known at that time. Mendeléeff himself points out forerunners who had compared small groups of similar elements, but adds, "they merely wanted the boldness necessary to place the whole question at such a height that its reflection on the facts could be clearly seen."

All the elements were now arranged for the first time in the order of their atomic weights, whereupon they were seen to be periodic in that they fell into successive lines of a table in which similar elements came in the same vertical column. There were gaps and discrepancies, but closer study justified Mendeléeff's classification.

As regards the gaps, Mendeléeff had the courage to predict that new or *eka*-elements would be discovered with properties which he described in remarkable detail. There are diamatic moments in the intellectual progress of mankind, when the force of controlled imagination leads to the discovery of a reality in nature. Thus the calculations of Adams and Leverrier had predicted the existence and position of an unknown planetary body, which was then found by Galle in its prescribed place and called the planet Neptune. Similarly, in 1875 Lecoq de Boisbaudran discovered a new element gallium with all the properties of *eka*-aluminium. In 1879 Nilson described scandium and in 1886 Winkler, germanium. These were *eka*-boron and *eka*-silicon.

Even Madame Curie's polonium, named for yet another country, and not discovered until the twentieth century, was Mendeléeff's *dvi*-tellurium. Another name for it is radium F. This brings out something that Mendeléeff did not foresee, the series of radioactive elements and another group due largely to Ramsay, the so-called rare or inert gases which now form our street signs. Now the system of 92 elements is complete

D. MENDELÉEFF—JANUARY 27, 1834–JANUARY 20, 1907

with the heaviest element uranium of atomic number 92. The atomic number, which runs closely parallel to the atomic weights, has proven in recent years to be more fundamental even than atomic weights, for now, for most elements, it has been found that there exists a group of isotopes almost identical, save in atomic weight. The impetus to all this later work was given by Mendeléeff, and its constant guide has been his classification. The key to a partial explanation has since been given by our later discoveries of the constitution of the atom. Much remains to be done before we have a complete system of the structure of the nuclei.

Jeans has suggested that since our observations are confined to the surface of the earth and the outer atmospheres of the stars and since the earth itself is only a sample of the outer atmosphere of the sun, our 92 elements may constitute only a small fraction of the weight of the universe. In this connection it is interesting that within the last few weeks there is reported the deliberate creation by Fermi of Naples of a new element of atomic number 93 by adding one unit to uranium. We recognize ever more clearly the prophetic insight which may be attained or vouchsafed into fundamental realities of nature.

Mendeléeff introduces his work on

Periods		Group 0	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
Type of Oxide Type of Hydride		—	R_2O RH	RO RH_2	R_2O_3 RH_3	RO_2 RH_4	R_2O_5 RH_3	$R_2O_6(RO_3)$ RH_2	R_2O_7 RH	RO_4 —
			A B	A B	A B	A B	A B	A B	A B	
First short period		He 2 4.002	H 1 1.0078 Li 3 6.94	Be 4 9.02	B 5 10.82	C 6 12.00	N 7 14.008	O 8 16.00	F 9 19.0	
Second short period		Ne 10 20.183	Na 11 22.997	Mg 12 24.32	Al 13 26.97	Si 14 28.06	P 15 31.02	S 16 32.06	Cl 17 35.46	
First long period	Even Series	Ar 18 39.94	K 19 39.1	Ca 20 40.07	Sc 21 45.1	Ti 22 47.9	V 23 50.96	Cr 24 52.01	Mn 25 54.93	Fe 26 Co 27 Ni 28 55.84 58.94 58.69
	Odd Series		Cu 29 63.57	Zn 30 65.38	Ga 31 69.72	Ge 32 72.6	As 33 74.93	Se 34 79.2	Br 35 79.92	
Second long period	Even Series	Kr 36 82.9	Rb 37 85.44	Sr 38 87.63	Y 39 88.92	Zr 40 91.22	Cb 41 93.1	Mo 42 96.0	Ma 43 ?	Ru 44 Rh 45 Pd 46 101.7 102.91 106.7
	Odd Series		Ag 47 107.88	Cd 48 112.41	In 49 114.8	Sn 50 118.7	Sb 51 121.77	Te 52 127.5	I 53 126.93	
Third long period	Even Series	Xe 54 130.2	Cs 55 132.81	Ba 56 137.36	La 57 138.9	Ce 58 140.13				
	Odd Series			The Rare Earth Elements. Atomic Numbers 59-71						
Fourth long period	Even Series					Hf 72 178.6	Ta 73 181.5	W 74 184.0	Re 75 188.7	Os 76 Ir 77 Pt 78 190.8 193.1 195.23
	Odd Series		Au 79 197.2	Hg 80 200.61	Tl 81 204.39	Pb 82 207.22	Bi 83 209.0	Po 84	—85	
Fifth period		Rn 86 222	—87	Ra 88 225.97	Ac 89	Th 90 232.12	UX_2 91	U 92 238.14		

PERIODIC CLASSIFICATION OF THE ELEMENTS—MENDELÉEFF (MODIFIED)
THE NUMBER AT THE RIGHT OF THE SYMBOL IS THE ATOMIC NUMBER OF THE ELEMENT, AND THE NUMBER BELOW IS THE ATOMIC WEIGHT.

"Solutions" in the following interesting lines:

This investigation is dedicated to the memory of a mother by her youngest offspring. Conducting a factory, she could educate him only by her own work. She instructed by example, corrected with love, and in order to devote him to science she left Siberia with him, spending thus her last resources and strength.

When dying, she said, "Refrain from illusions, insist on work, and not on words. Patiently search divine and scientific truth." She understood how often dialectical methods deceive, how much there is still to be learned, and how, with the aid of science without violence, with love but firmness, all superstition, untruth, and error are removed, bringing in their stead the safety of discovered truth, freedom for further development, general welfare, and inward happiness. Dmitri Mendeléeff regards as sacred a mother's dying words. October, 1887.

The centenary of Mendeléeff's birth has recently been commemorated by the London Chemical Society with an address by Lord Rutherford. A much more elaborate celebration is arranged to take place in Leningrad and Moscow over a period of five days, beginning on September 10. Invitations have been issued to a number of foreign guests, and reports will be read relating the great progress recently made by the very numerous scientific institutes in support of which the U. S. S. R. spent in 1933 no less a sum than $320,000,000.

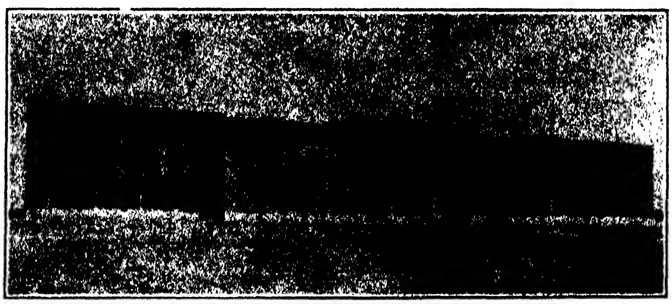
The Soviet postal authorities have issued a series of new postage stamps of five and twenty kopek denominations, bearing a design of the Mendeléeff monument against a background of his table of the periodic system of elements; the ten and fifteen kopek denominations bear a portrait of Mendeléeff, also against a background of the table of the periodic system of elements. All bear the commemoration date 1834–1934.

J. W. McBain

THE INTERNATIONAL CHEMISTRY MEETINGS AT MADRID

EARLY in April Spain was hostess to two international congresses in the field of chemistry, bringing together some 1,200 chemists from all over the world. Before the world war it had become the custom to hold an International Congress of Pure and Applied Chemistry every three years in a different country. In 1909 the seventh congress was held in Rome; and in 1912 the eighth congress was held in Washington, D. C., and New York. The latter was an auspicious event, bringing many of the notables of Europe to America. The ninth congress was scheduled for Russia in 1915, but the world war interfered and there was no resumption of these international gatherings until the recent one.

In the afternoon Dr. Gilbert N. Lewis, professor of chemistry and dean of the college of chemistry at the University of California, lectured on "Different Kinds of Water" in the auditorium of the University of Madrid. Distinguished chemists from many lands presented lectures on as many different phases of theoretical and applied chemistry. There were 34 general and special lectures, but in all some 300 papers were presented. The importance of organic chemistry was clearly brought out, for several times as many papers were devoted to organic chemistry as to inorganic chemistry. A further analysis shows that 57 papers were presented in organic chemistry, 55 in biochemistry,

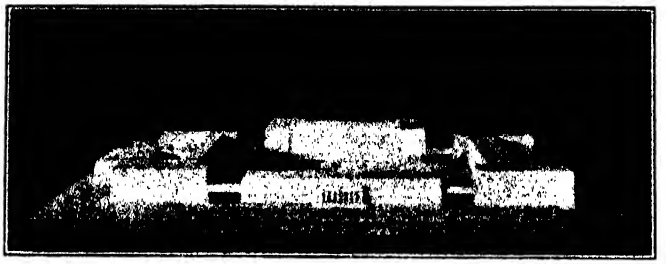


THE NATIONAL INSTITUTE OF PHYSICS AND CHEMISTRY

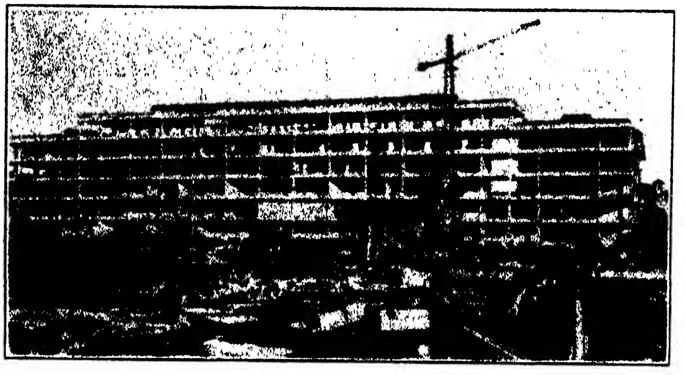
44 in analytical chemistry and 16 in agricultural chemistry, while only 26 of the papers were classified as pure and applied *inorganic* chemistry.

At the opening session of the congress in the Capital Theater at Madrid General Secretary Professor Enrique Moles gave the address of welcome. The president of the congress, Professor Obdulio Fernandez, gave an address on the advance of chemistry since the previous congress. This was followed with a short talk by Professor E. Biilmann, president of the International Union of Chemistry. This impressive session was brought to a close by President Zamora, of the Spanish Republic, who was seated with the officers on the stage during the morning. The keen insight of this ruler into scientific developments and their significance was a revelation. His genial character and cordiality made one feel at home at once in Madrid.

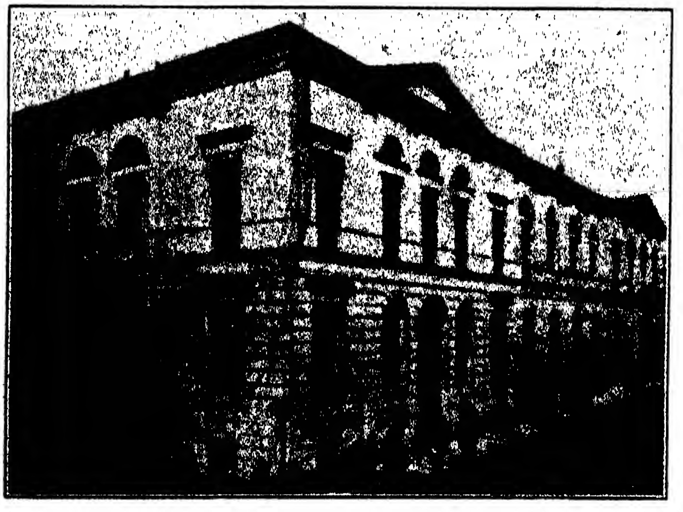
The American representatives, recommended to the State Department by the National Research Council and the National Academy of Sciences and sent as official delegates, were: Dr. Arnold K. Balls, U. S. Bureau of Chemistry; Dr. Edward Bartow, State University of Iowa, chairman; Dr. J. van N. Dorr, New York; Dr. Raleigh Gilchrist, U. S. Bureau of Standards; Dr. Lauder W. Jones, Princeton University; Dr. Gilbert N. Lewis, University of California; Dr. Atherton Seidell, National Institute of Health; Dr. Alexander Silverman, University of Pittsburgh; Dr. Robert E.



THE NEW FACULTY OF SCIENCES
A PLASTIC MODEL SHOWING THE INSTITUTE OF CHEMISTRY IN THE BACKGROUND.



THE STATE OF CONSTRUCTION
OF THE INSTITUTE OF CHEMISTRY OF THE FACULTY OF SCIENCES SHORTLY BEFORE THE CONGRESS CONVENED.

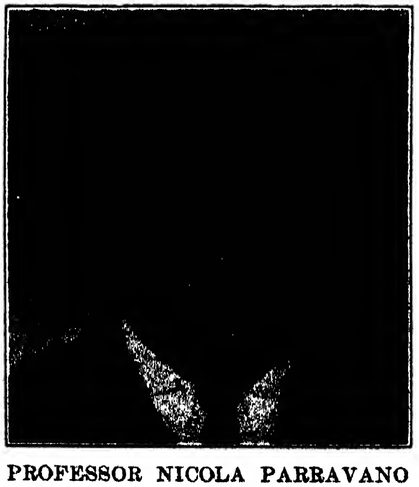


THE INSTITUTE OF CHEMISTRY OF THE FACULTY OF SCIENCES

PROFESSOR E. BIILMANN
RETIRING PRESIDENT OF THE INTERNATIONAL UNION OF CHEMISTRY.

Swain, Leland Stanford University; Dr. John W. Turrentine, U. S. Bureau of Chemistry.

On the second day there was a most impressive ceremony in the great hall of the university, where honorary doctor of science degrees were conferred upon Professors Nicola Parravano of Rome,



PROFESSOR NICOLA PARRAVANO
NEWLY ELECTED PRESIDENT OF THE INTERNATIONAL UNION OF CHEMISTRY AND RECIPIENT OF AN HONORARY DOCTOR OF SCIENCE DEGREE.

Henry Armstrong of London, Henri le Chatelier of Paris, Paul Walden of Rostock and Gilbert N. Lewis of Berkeley. Doctor of pharmacy degrees were conferred upon Professors Robert Robinson of Oxford, Paul Karrer of Zurich and Ernest Fourneau of Paris. The colorful ceremonials accompanying these events in European universities added to the dignity and impressiveness of such occasions. It might be noted that two of the men honored were octogenarians,

PROFESSOR ENRIQUE MOLES
GENERAL SECRETARY OF THE NINTH INTERNATIONAL CONGRESS OF PURE AND APPLIED CHEMISTRY, WHO GAVE THE ADDRESS OF WELCOME.

namely, Professor Armstrong and Professor le Chatelier, each of whom is 84 years of age, the first the dean of British chemists, the second, the dean of French chemists. Following the ceremony there was the customary serving of refreshments, wine and champagne, cakes and sandwiches. This seems to be an indispensable part of such events in Spain.

At a meeting of the Spanish Academy of Sciences, Professors G. Garger of Edinburgh, E. Bartow of the State University of Iowa, G. B. Bonino of Bologna, G. Bertrand of the Pasteur

Institute, F. Fichter of Basle, S. P. Sorensen of Copenhagen, E. Späth of Vienna and E. Votocek of Prague were elected fellows of the academy. We should bear in mind that America has been doubly honored in the conferring of the doctor of science degree upon Professor Gilbert N. Lewis by the University of Madrid and the election of Dr. Edward Bartow as a fellow of the Spanish Academy of Sciences.

The closing session of the Ninth Congress of Chemistry and Eleventh Conference of the International Union were held in the great hall of the university. Professor Nicola Parravano of Rome was elected to succeed Professor E. Biilmann of Copenhagen as president of the International Union. It was voted that the next meeting of the Union should be held in Switzerland in 1936. On this occasion expressions of appreciation to Spain for her wonderful hospitality followed in resolution upon resolution. There is no doubt that the government and the business men of Spain must have spent hundreds of thousands of pesetas for the elaborate entertainment of their guests and for the publication of reprints, maps, guide books and exquisitely illustrated volumes on chemistry in Spain and on centers of especial interest. These will ever remain precious souvenirs to those who were fortunate enough to attend the Ninth International Congress of Pure and Applied Chemistry.

Too much can not be said of the extraordinary development in chemical science in Madrid and undoubtedly in other centers in Spain as well. The National Institute of Physics and Chemistry, located in the university, which was founded in 1513 and which now has a student enrolment of over 12,000, already occupies a building provided with well-equipped laboratories, and there is under construction a new laboratory, magnificent in design and gigantic in plan and scope. It will cover at least the equivalent of four American city blocks. The educational system in vogue is worthy of comment. Except for special lectures, the lecture system has largely been abandoned. Students are given every possible facility in libraries and laboratories and resort to conferences and independent investigations for their advancement. Under the sound guidance of their professors they are developing a self-reliance and an ambition for search and investigation which will unquestionably place Spain in the front ranks in the development of chemical science.

The meeting of the International Congress of Chemistry and of the Union in Madrid will ever be a memorable one in the minds of those who were fortunate enough to enjoy the wonderful hospitality of Spain. Much of the credit is due to the efforts of President Obdulio Fernandez and Secretary Enrique Moles of the congress.

ALEXANDER SILVERMAN

THE MOUNT ST. KATHERINE SOLAR OBSERVATORY

AN American astronomer and his family recently started housekeeping on the summit of Mount St. Katherine in the Sinai Peninsula.

Their cozy granite-block dwelling house, erected for them by the monks of Saint Katherine's Monastery, who are their nearest neighbors, may stand close to the very spot where, in the opinion of some Biblical scholars, Moses received the ten commandments, according to the description in the book of Exodus.

A short distance away on the very peak stands the new observatory, also erected by the monks, where Harlan H. Zodtner, of the Smithsonian Institution, will make daily observations of the radiation output of the sun. Dr. Charles G.

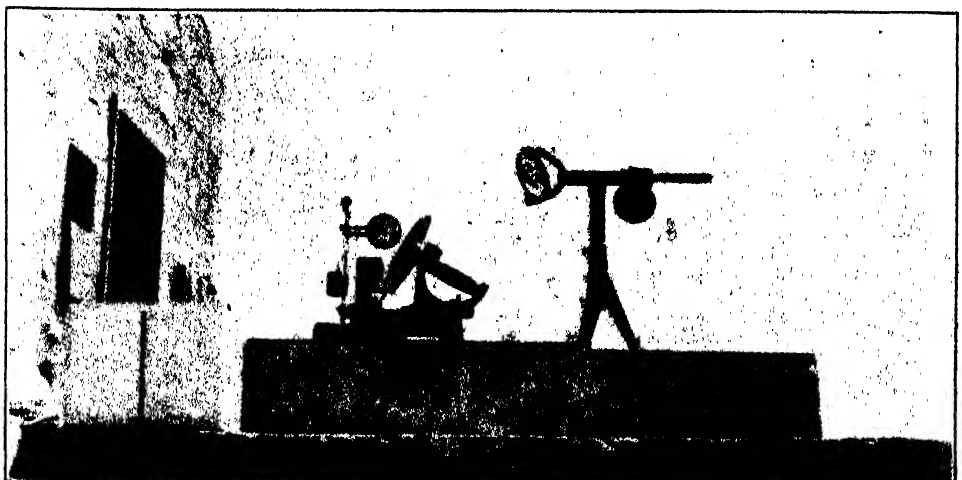
MOUNT SAINT KATHERINE SOLAR OBSERVATORY

THE DWELLING HOUSE AND SHOP

Abbot, secretary of the Smithsonian Institution, has the signed contract between Zodtner and His Beatitude Porphyrios the Third, archbishop of Mount Sinai, acting on behalf of the convent of Mount Sinai. Under this agreement the dwelling and observatory were erected by the monks and will become the property of the monastery when the institution is through with them. The monks also constructed a road to the observatory and a masonry enclosure around the mountain spring.

The monastery itself, 10 miles away in the valley of Wady el-Der, is one of the oldest in Christendom, and the monks themselves had their nativity in many lands. They have been extremely friendly to their new neighbors. Primitive Christianity and modern science in one of its most advanced branches have entered into a cordial partnership in this strange land, over whose desolation is the glamor of supernatural tradition.

Aside from the monks, Mr. Zodtner, his family and his assistant, Mr. F. A.



COELOSTAT FOR REFLECTING SOLAR RAYS INTO THE OBSERVATORY

Greeley, expect few human contacts. There are occasional pilgrims, however, and during the summer Bedouin herdsmen drive their sheep and goats up the mountain sides to take advantage of the scant pasturage around the high springs.

This is not the first time, it is probable, that the summit of Mount St. Katherine has been used as an astronomical observatory, of a sort. Arabs as early as the sixth century were conducting worship of the ancient moon god Sin on the summits of the Sinai mountains and may have set up one of their strange altars on the very site of the Smithsonian observatory.

Mr. Zodtner, in letters just received at the Smithsonian, reports that his family, consisting of his wife and two small children, is comfortably situated on the sacred mountain top except for the lonely desolation of the site. He already has started to make observations, observing on 15 days in January and 21 days in February with nearly cloudless skies.

Mount St. Katherine was selected as the site for the observatory after a long search over Africa and Asia for the highest, driest accessible spot in the eastern hemisphere where low wind velocities prevail. It represented the best combination of these conditions that could be found. For years the Astrophysical Observatory of the Smithsonian, under the direction of Dr. Abbot, has been measuring daily the amount of solar radiation in different parts of the western hemisphere—at Washington, Table Mountain in California and Mount Montezuma, Chile. This patient work is beginning to lead to important conclusions concerning variations in the earth's weather, and progress has been especially rapid during the past year.

But reliable data from the eastern hemisphere are desirable in order to multiply the chances of observing the sun's heat every day without breaks. For the sun is a slightly variable star. Its variations can not be accurately predicted. Daily observations are required to make complete the investigation of relations of weather to the sun's heat. It is to secure such data that Mr. Zodtner has set up his instruments on Mount St. Katherine.

Few spots on earth approach the ideal for these delicate measurements. What is measured is the amount of heat from the sun that falls at any given time on a hypothetical black object with the dimensions of a cubic centimeter, placed at the edge of the earth's atmosphere. Nobody, of course, can get to the edge of the atmosphere to place and observe such a cube. It must be an imaginary cube, with the amount of heat it absorbs measured somewhere on the earth's surface. The radiation that actually comes through to the surface is far different in amount from that which would be received by the hypothetical black body, because of the very great complications brought about by the content of the atmosphere itself.

First of all, there must be a completely cloudless sky. Secondly, the air is full of water. Water absorbs radiation, especially at the lower edge of the spectrum from the limits of the visible red far into the invisible infra-red. So it is essential to find a mountain in a desert where the water vapor will be at a minimum.

Thirdly, the minute dust particles in the atmosphere scatter the radiation over the sky. So there must be a minimum of dust. Fourthly, the delicacy of the measurements requires nearly calm winds in order to observe with the accuracy demanded. Mount St. Katherine comes close to satisfying all these conditions.

ELEMENT NUMBER 93

HAS a super-uranium, the first of a series of elements heavier than the recognized 92 chemical building blocks, been discovered? Dr. Enrice Fermi, 32-year-old physicist of the Royal University of Rome, by atomic bombardment has reported that he can artificially create a new element, No. 93. He obtained this result by bombarding uranium, heaviest of elements, with neutrons.

Uranium is the heaviest element found in nature, being 238 times as dense as hydrogen, the lightest. For many years it was thought to be the limit of all the possible elements, but recently Sir Arthur Eddington and other theoretical scientists have calculated the maximum number of possible elements as 136. Element No. 93 of Dr. Fermi, if its reality is substantiated by competent investigators working independently, may be the first of the super-heavy substances lying beyond uranium in the gamut of chemical elements.

Opinion among American physicists regarding Dr. Fermi's discovery indicates that if still-heavier elements are found they will be transitory substances breaking down like the naturally radioactive elements such as radium but probably much faster. For the provisional element No. 93 it is reported to take only 13½ minutes for the initial quantity of the element to "decay" or disintegrate to half the amount.

By what proof Dr. Fermi bases his report on the actuality of element No. 93 is still unannounced. In his recent communication to the British scientific journal, *Nature,* however, he cites twenty-three cases where he had been able to produce artificial radioactivity in a variety of elements with the same apparatus he employed for creating element No. 93. In recounting his work Dr. Fermi told of observing electrons being given off as the man-made radioactive substances decayed away. Thus he differed with the earlier research of Irene Curie and Professor F. Joliot of Paris, who have observed positrons being omitted in the process.

The atomic happenings which might account for the creation of the new element out of uranium are still a subject of debate and conjecture among scientists. One possible occurrence might be that the neutrons used by Dr. Fermi (consisting, if they do, of a positive particle, the proton and a negative charge, the electron) might break into two parts on impact with the nucleus of the uranium atoms. The proton might embed itself within the uranium nucleus and so increase the weight of the atom to No. 93, while the electron part of the neutron would be given off in the process and be detectable either with electrical instruments known as Geiger counters or by photographing the electron tracks in a Wilson cloud chamber.

The best way to determine whether the new element No. 93 really exists would be to weigh it on the atomic "scales"—the mass spectrograph. It does not appear that this crucial test has been applied in Dr. Fermi's work, for no mention was made of the method.

What amazes American scientists regarding Dr. Fermi's experiments is that his source of bombarding neutrons is comparatively weak. In a small glass tube the Italian scientist placed beryllium and the radioactive gas, radon, given off by radium as it breaks up. The action of the radon on the beryllium caused swift-moving neutrons to come off which struck a nearby bit of uranium. About 100,000 neutrons were liberated in this fashion each second. In America sources of neutrons have been developed which are capable of giving off 100 times this number per second.

It is only since the beginning of 1934 that the technique of creating artificial radioactivity in normally stable elements

has been known to the world of science. On January 31 Irene Curie (daughter of the late Madame Curie, discoverer of radium) and her husband, M. F. Joliot, announced that by bombarding the elements boron, magnesium and aluminum with the heavy cores of helium atoms they were able to create transitory radioactive forms of nitrogen, silicon and phosphorus.

Substantiation of the Curie-Joliot experiments followed swiftly from the Cavendish Laboratory at the University of Cambridge, England, and from the California Institute of Technology and the University of California in America. In England the favorite atomic bombarding particles have been the cores of hydrogen atoms—the protons. In the California experiments the cores of the new heavy hydrogen—the deutons—have been driven at a variety of elements to produce artificial radioactivity.

Work prior to that of Dr. Fermi on the creation of artificial radioactivity has all been accomplished by using relatively light-weight elements as targets. That the same phenomena could be produced in the heaviest and most complicated atom of all, uranium, was unknown. For uranium, and the whole series of elemental offspring which finally ends when lead is reached, it was known that natural radioactivity was occurring with elements gradually turning into substances of slightly less weight. Many experiments seemed to indicate that nothing man could do would change the rate at which the natural disintegration occurred, either to slow it down or speed it up. If Dr. Fermi's work on the creation of element No. 93 is substantiated later by other scientists it will be the first case where the hitherto impregnable sequence of natural radioactivity change has been altered.

SCIENCE SERVICE

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THE REALM OF THE NEBULAE

By Dr. EDWIN HUBBLE

MOUNT WILSON OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON

The Exploration of Space

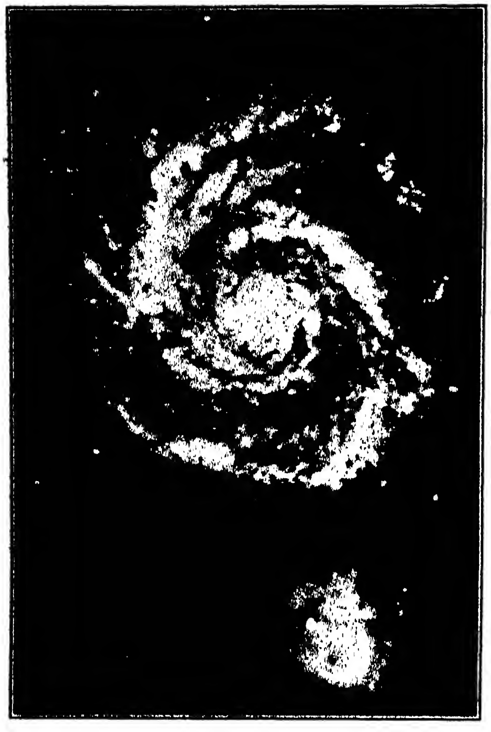
I propose to discuss some of the recent explorations in the realm of the nebulæ which bear directly on the structure of the universe. The earth we inhabit is a member of the solar system. The sun with its family of planets seems isolated in space, but the sun is merely a star—one of the millions which populate our particular region of the universe. The stars are scattered about at enormous intervals, but on a still greater scale they are found to form a definite system, again isolated in space. On the grand scale we may picture the stellar system drifting through the universe as a swarm of bees drifting through the air.

From our position somewhere within the system, we look out through the swarm of stars, past the borders, into the universe beyond. It is empty for the most part—vast stretches of empty space. But here and there, at immense intervals, we find other stellar systems, comparable with our own. They are so distant that in general we do not see the individual stars. They appear as faint patches of light and hence are called nebulæ, *i.e.*, clouds.

The nebulæ are great beacons, scattered through the depth of space. We see a few that appear large and bright. These are the nearer nebulæ. Then we find them smaller and fainter in constantly increasing numbers, and we know we are reaching out into space farther and ever farther until, with the faintest nebulæ that can be detected with the greatest telescope, we have reached the frontiers of the known universe. This last horizon defines the Observable Region—the region of space which can be explored with existing telescopes. It is a vast sphere, some 600 million light years in diameter, throughout which are scattered 100 million nebulæ.

The question immediately arises as to whether the nebulæ form an isolated super-system, analogous to the system of the stars but on a still grander scale. Actually, we find the nebulæ scattered singly, in groups and occasionally in great clusters, but when very large volumes of space are considered, the tendency to cluster averages out and to the very limits of our telescopes the distribution is approximately uniform. If the observable region is divided into 100, 1,000 or even 10,000 equal parts, the nebular contents of the various fractions are very closely similar. There is no evidence of a thinning out, no trace of a physical boundary. The realm of the nebulæ, we must conclude, stretches on and on, far beyond the frontiers.

Observations give not the slightest hint of a super-system of nebulæ. Hence, for purposes of speculation, we may invoke the principle of the uni-



THE "WHIRLPOOL NEBULA" (M. 51 IN CANES VENATICI)

THIS, THE FIRST NEBULA IN WHICH THE SPIRAL STRUCTURE WAS DISCERNED, IS ABOUT ONE MILLION LIGHT YEARS FROM THE EARTH. (TAKEN AT MT. WILSON OBSERVATORY OF CARNEGIE INSTITUTION.)

formity of nature and suppose that any other equal portion of the universe, chosen at random, will exhibit much the same general characteristics as the region we can explore with our telescopes. As a working hypothesis, serviceable until it leads to contradictions, we may venture the assumption that the realm of the nebulæ is the universe—that the Observable Region is a fair sample and that the nature of the universe may be inferred from the observed characteristics of the sample.

Characteristics of the Observable Region

The characteristics of the Observable Region as a whole forms the main subject of the present discussion, but a brief appendix will be added, indicating the kind of information concerning the universe we may hope to infer from the sample.

We are situated, by definition, at the center of the Observable Region. Our immediate neighborhood—the system of the planets—we know rather intimately, but our knowledge fades rapidly with increasing distance. We know something about the stars, a little about the nearer nebulæ, almost nothing about the more remote nebulæ save their directions, their apparent luminosities and the nature of the light which they emit. Information concerning the Observable Region as a whole is thus restricted to the most general features only—the distribution of nebulæ and the more conspicuous characteristics of their spectra. These data, together with the general laws of nature, which we assume to hold everywhere, are our present clues to the nature of the universe.

Let us start with distribution. The nebulæ are beacons scattered through space. In order to determine their distribution it is necessary to know their intrinsic luminosity, *i.e.*, their candle power—both the average luminosity and the range. If some nebulæ were intrinsically a million times brighter than others, as is the case with stars, the problem of the distribution would be extremely difficult, for apparent faintness would then be a very poor indication of distance. Fortunately, the nebulæ are all of the same order of intrinsic luminosity. This information was derived as follows.

Distances of Nebulæ

The nebulæ are stellar systems, and some of them are so near that a few of the individual stars can be detected with the modern reflectors. Stars are the fundamental criteria of nebular distances. We know something about stars and wherever we find them we can gen-

erally recognize their types, estimate their candlepowers, and so derive their distance from their apparent faintness. In a dozen of the nearest nebulæ, various types of stars are clearly recognized and distances are rather accurately determined.

For instance, some 40 cepheid variable stars are found in M31, the great spiral nebula in Andromeda. Such stars in our own system average about 3,000 times as bright as the sun. In the spiral they appear about 150,000 times fainter than the faintest star that can be seen with the naked eye. A simple calculation indicates that the spiral must lie at a distance of nearly a million light years. Other types of stars which can be recognized in the nebula indicate the same order of distance, and hence we consider that the results are reliable. Such accuracy, however, is attained only for a very few of the nearest nebulæ.

In several dozen other nebulæ we can detect a few stars, but can not recognize their types. Nevertheless, we have many reasons for supposing that there is an upper limit of stellar luminosity and that this limit, about 60,000 times as bright as the sun, is in general attained and seldom surpassed in all the great systems of stars. Hence we may assume that the brightest stars in all nebulæ are 60,000 times as bright as the sun and estimate their distances from their apparent faintness. The results may not be accurate individually, but they are reliable for statistical purposes.

Finally, the great cluster in Virgo, a compact group of several hundred nebulæ, is so near that a few stars can be seen in a few of its members. These stars indicate the distance of all the several hundred nebulæ in the cluster. The twenty known clusters, moreover, are all similar groups, and their relative distances were already known. Hence the distance of the Virgo cluster indicates the distances of them all.

In this way it has been possible to assemble a sample collection of several thousand nebulæ whose distances and hence whose real luminosities and dimensions are known. An analysis of the sample collection indicates at once that the nebulæ are all of the same order of luminosity. They average about 80 million times as bright as the sun. The brightest are about 10 times brighter than the average and the faintest are about 10 times fainter, but the majority fall within the narrow limits from a half to twice the average of them all. The mean of any considerable number, say 100 nebulæ, chosen at random will be closely similar to the general average. For statistical purposes, where large numbers are concerned, we may assume that the nebulæ are equally luminous and that their apparent faintness indicates their distances.

Distribution of Nebulæ

The distribution of nebulæ can therefore be studied by counting the numbers

SPIRAL NEBULA IN URSA MAJOR (M. 101)

THE REGION OF SPACE WHICH CAN BE EXPLORED WITH EXISTING TELESCOPES IS A VAST SPHERE, 600 MILLION LIGHT YEARS IN DIAMETER, THROUGHOUT WHICH 100 MILLION NEBULÆ ARE SCATTERED. (Taken at Mt. Wilson Observatory.)

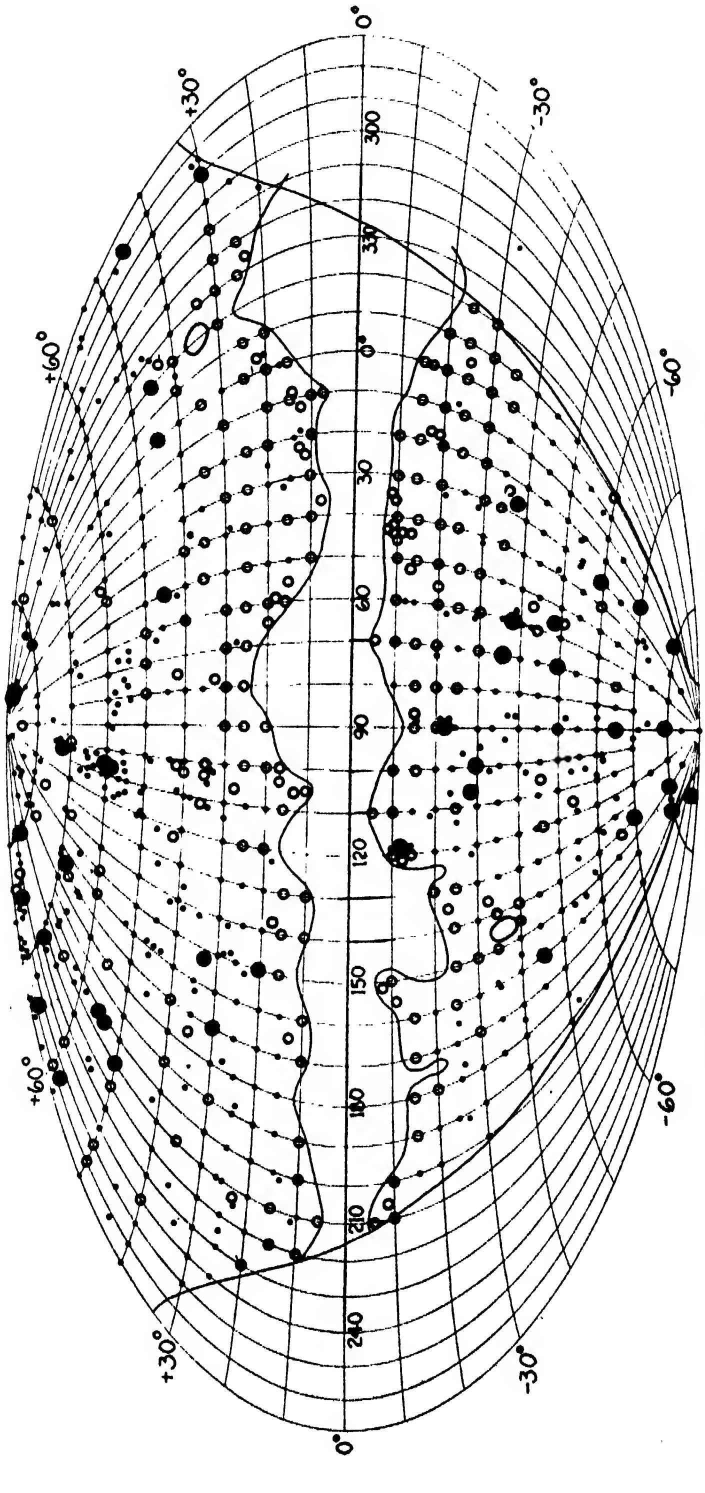


DIAGRAM SHOWING THE DISTRIBUTION OF SPIRAL NEBULÆ

FROM COUNTS MADE BY DR. HUBBLE ON PHOTOGRAPHS DISTRIBUTED AT INTERVALS OVER THE WHOLE NORTHERN SKY. THE HORIZONTAL LINE IS THE PLANE OF THE GALAXY, AND THE FIGURES GIVE GALACTIC LONGITUDE. IT SHOULD BE NOTED THAT SPIRALS AVOID THE REGION OF THE GALAXY.

of nebulæ to successive limits of apparent faintness. The results represent numbers of nebulæ in spheres of successively greater radii, and the differences give the numbers of nebulæ in successive spherical shells. In this way the numbers of nebulæ per unit volume, *i.e.*, the density distribution of nebulæ, has been explored throughout the observable region. To a first approximation the density distribution is uniform. Each volume of space, represented by a sphere with a radius of 10 million light years, contains on the average about 2,500 nebulæ. Each nebula is about 80 million times as bright as the sun and perhaps 800 million times as massive. On the average, the nebulæ are about one and a half million light years apart.

The uniform distribution of nebulæ means that, on the grand scale, the density of matter in space is uniform and we can calculate the density. There is, on the average, one nebula, 800 million times as massive as the sun, for every billion billion cubic light years or roughly one sun per billion or thousand million cubic light years. In ordinary units this is equivalent to one gram per 10^{30} cubic centimeters, and may be visualized as corresponding to a grain of sand in each volume of space equal to the volume of the earth. The nebulæ are scattered very thinly, and space is mostly empty.

In this calculation we consider only the matter concentrated in nebulæ. There is doubtless matter scattered between the nebulæ which has been ignored. How much, we do not know; we can only say that there is not sufficient to be detected—not enough to appreciably dim the most distant nebulæ that can be observed.

Velocity-Distance Relation

The second characteristic of the Observable Region, the velocity-distance relation, introduces the subject of spectrum analysis. When a light source is viewed through a glass prism, the various colors of which the light is composed are spread out into an ordered sequence, represented, for instance, in the rainbow. The sequence never varies, each color has its place. Different colors represent light of different wave-lengths. From the short waves of violet light, the waves lengthen steadily through the spectrum to the long waves of the red at the other end.

Three kinds of spectra are generally distinguished. An incandescent solid, e.g., electric light filament, radiates all possible colors or wave-lengths; hence its spectrum is continuous from violet to red.

An incandescent gas, *e.g.*, a neon tube, radiates only a few isolated colors, hence its spectrum consists of isolated bright spots or lines distributed in a certain pattern. This is called an emission spectrum. The pattern of bright lines is characteristic of the particular gas involved, and unknown gases are very readily identified from their spectra alone.

Finally, there are absorption spectra. When an incandescent solid, giving, of course, a continuous spectrum, is surrounded by a cooler gas, *e.g.*, a star surrounded by an atmosphere, the gas absorbs just those colors which it would radiate if itself incandescent. This absorption produces dark spaces or lines in the otherwise continuous spectrum of the background. The patterns of these dark lines identify the gases in the atmospheres of the stars.

The study of absorption spectra is the dominating feature of modern astronomy. They furnish an astonishing amount of information concerning the physical condition of stars and even of planets and of nebulæ. Either directly or indirectly they indicate surface temperatures of stars, surface luminosities, total luminosities, distances, velocities in the line of sight.

The significance of spectra may be indicated by a homely demonstration.

ONE OF THE MOST BEAUTIFUL OF THE SPIRAL NEBULÆ (M. 81 IN URSA MAJOR)

ITS LIGHT TAKES 1,600,000 YEARS TO REACH US. THE CENTRAL REGION IS UNRESOLVED BUT IN THE OUTER PORTIONS SWARMS OF STARS ARE VISIBLE. THESE ARE SIMILAR TO THE VERY BRIGHT STARS IN OUR OWN GALACTIC SYSTEM. (TAKEN AT MT. WILSON OBSERVATORY.)

From Mt. Wilson the lights of some sixty cities and towns are visible, spread over the valley below. A direct photograph with a camera shows swarms of lights similar to a field of stars, but tells nothing as to the nature of the lights. When a glass prism is placed in front of the camera lens, each light is spread out into a spectrum. Then the differences appear. The filament lamps show continuous spectra, arc lights show the emission spectra of carbon vapor, neon signs show two or three isolated colors. In the same way a direct photograph of the sky shows a field of stars. Except for their different luminosities the stars all appear alike. A photograph of the same field, with a prism in front of the lens, shows each star drawn out into its spectrum, and differences in the nature of the light are at once apparent.

Yellow stars like the sun show the absorption of hydrogen and of iron vapor in their atmospheres and, near the violet end, a pair of strong dark lines due to calcium absorption. These latter, the H and K lines of calcium, are the most conspicuous feature of the spectra and are unmistakable wherever they are found. On the same scale, the spectra of nebulæ resemble those of yellow stars. The H and K lines are readily recognized, and certain hydrogen and iron lines as well.

The spectra of nebulæ, however, exhibit a peculiar characteristic in that the details—the dark lines—are not in their usual positions. The lines are all displaced toward the red end of the spectrum and the displacements increase with the faintness of the nebulæ observed. The observations are summed up in the statement—the fainter the nebula, the larger the red-shift.

Now apparent faintness of nebulæ is confidently interpreted in terms of distance; hence we can restate the observational results in the form—red-shifts increase with distance. Precise investigations indicate that the relation is linear —red-shifts are equal to distances times a certain constant.

The relation was first established about five years ago among the brighter nearer nebulæ for which Dr. Slipher, of the Lowell Observatory, had assembled his collection of spectra representing the pioneer work in the field. Since then the list of spectra has been more than trebled by Mr. Humason, using the large reflectors on Mt. Wilson. With the 150 red-shifts now available, the distance relation has been confirmed and extended to the limit at which spectra can be recorded with existing instruments. Out to 150 million light years, the red-shifts increase at a uniform rate.

The significance of this strange characteristic of our sample of the universe

depends upon the interpretation of red-shifts. The phenomena may be described in several equivalent ways—the light is redder, the light waves are longer, the vibrations are slower (the pitch is lower), the light quanta have lost energy.

Many ways of producing such effects are known, but of them all only one will produce large red-shifts without introducing other effects which should be conspicuous but actually are not found. This one known permissible explanation interprets red-shifts as due to actual motion away from the observer. Rapid motion of recession drags out the light waves and, as it were, lowers the pitch. Red-shifts, we can say, are due either to actual motion or to some hitherto unrecognized principle of physics. Theoretical investigators almost universally accept the red-shifts as indicating motion recession of the nebulæ, and they are fully justified in their position until evidence to the contrary is forthcoming.

On this interpretation the nebulæ are rushing away from us, and the farther away they are, the faster they are traveling. The velocities increase by roughly 100 miles per second for each million light light years of distance. The present distribution of nebulæ can be represented on the assumption that they were once jammed together in our particular region of space, and at a particular instant, about 2,000 million years ago, they started rushing away in all directions at various velocities. The slower nebulæ, on this assumption, are still in our neighborhood, but the faster nebulæ are now far away. The faster they are traveling the farther they have gone. The time scale seems suspiciously short—a small fraction of the estimated age of some stars—and the apparent discrepancy suggests the advisability of further discussion of the interpretation of red-shifts as evidence of motion.

The largest red-shift actually recorded represents a velocity of about 15,000 miles per second at a distance of roughly 150 million light years. But nebulæ can be photographed out to distances twice or thrice the distances to which their spectra can be recorded. Hence, if the observed relation holds to the very frontiers of the observable region, we should encounter red-shifts corresponding to velocities of 30 or 40 thousand miles per second, say one fifth the velocity of light.

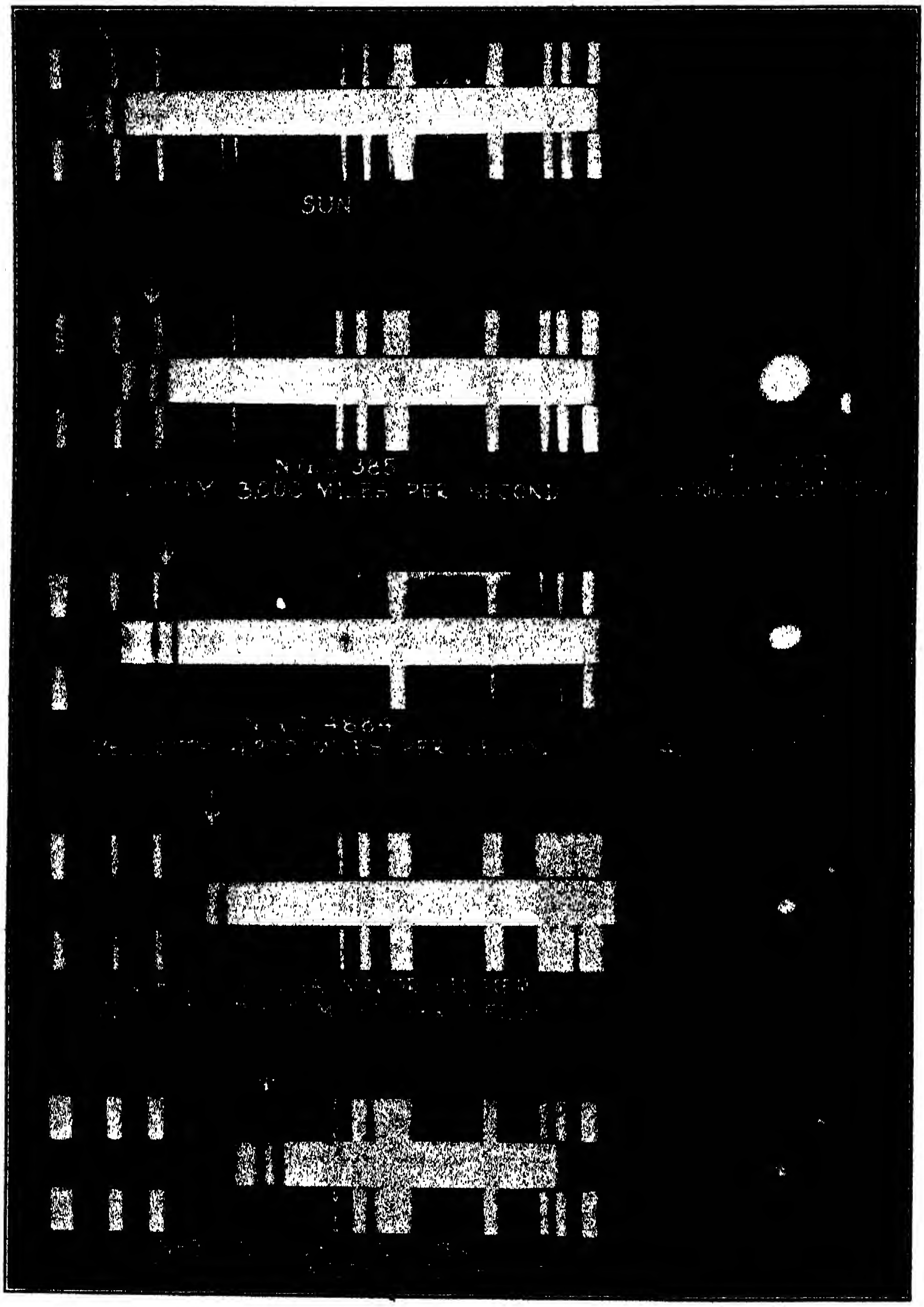
Such red-shifts are so enormous that we may expect appreciable indirect effects on colors and apparent luminosities. These effects are now under investigation. The field is new, but it offers very definite prospects not only of testing the form of the velocity-distance relation beyond the reach of the spectrograph, but even of critically testing the interpretation of red-shifts as actual motion. With this possibility in view, the cautious observer refrains from committing himself to the present interpretation and employs the colorless term "apparent velocity."

The Observable Region as a Sample of the Universe

Now, in conclusion, let us see what sort of information concerning the universe may be inferred from the observed characteristics of the sample. The sample is homogeneous and isotropic and the nebulæ appear to be rushing away from our particular position. These meager data, together with the general laws of nature, are all we have to guide us.

Mathematics deals with possible worlds, *i.e.*, logically consistent systems. Science attempts to determine the actual world in which we live. So, in cosmology, mathematics presents us with an infinite array of possible universes. The explorations of science are eliminating type after type, class after class, and already the residue has dwindled to more or less comprehensible dimensions.

Considerations of the laws of nature



WIDENED LOW-DISPERSION SPECTRA

WITH DIRECT PHOTOGRAPHS OF DISTANT EXTRA-GALACTIC NEBULÆ SHOWING LARGE RED SHIFT AND GIVING ESTIMATED RECESSION VELOCITIES. (TAKEN AT MT. WILSON OBSERVATORY.)

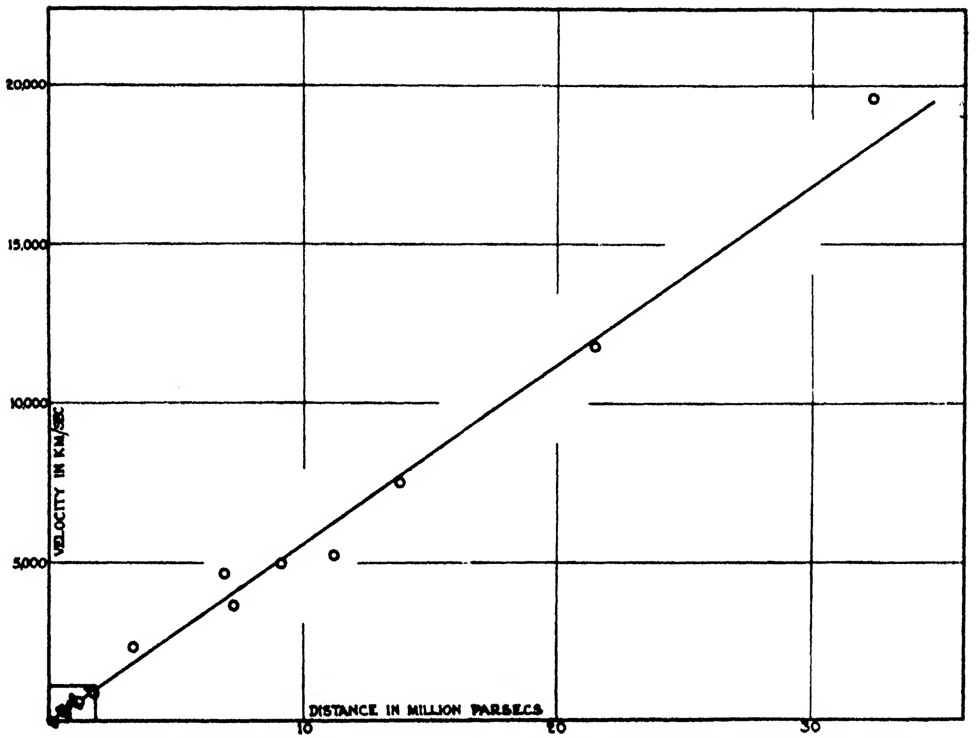


DIAGRAM SHOWING RELATION BETWEEN MEASURED VELOCITY AND DISTANCE OF SPIRAL NEBULÆ

THE VELOCITY IS MEASURED FROM SPECTROGRAMS TAKEN WITH THE 100-INCH REFLECTOR AT MT. WILSON OBSERVATORY AND THE DISTANCE IS DETERMINED FROM THE BRIGHTNESS OF THE NEBULÆ AS SHOWN ON DIRECT PHOTOGRAPHS.

led to the theory of relativity, developed by the genius of Einstein and now generally accepted. According to relativity, the large-scale geometry of space is determined by the contents of space. This dependence is expressed in Einstein's famous cosmological equation and modern cosmology is largely a series of attempts to solve the equation. It is a relation between symbols, and solutions are not possible until the symbols are interpreted. Observations as yet furnish only partial interpretations, and hence the various solutions already proposed incorporate a certain amount of guessing.

The most reasonable speculations run about as follows. Since the contents of space is distributed uniformly, the geometry of space must exhibit the same uniformity. Of all possible geometries, only three types fulfil this requirement completely. One is Euclidean geometry, so familiar to most of us that we ignore the very existence of others. Another is Riemannian geometry, and this it is which the consensus of opinion accepts as the most useful for describing the large-scale features of the universe.

Riemannian space with constant positive curvature follows more or less directly from the observed characteristics of our sample. This space is usually described as the three-dimensioned analogue of the sphere. Just as the surface of a sphere with its uniform positive curvature has a finite area but no boundaries, so the three-dimensional analogue,

with its uniform positive curvature, has a finite volume but no boundaries. In other words, we live in a finite universe.

The volume is determined by the radius of curvature (again like the area of the surface of a sphere) and the radius of curvature is determined by the amount of matter, *i.e.*, the density of matter, in space. The density actually observed, 10^{-30} grams per cubic centimeter, suggests a radius of about 3,000 million light years and a volume of the order of two or three million times the volume of the Observable Region. Such a universe would contain about 500 million million nebulæ. This is an instantaneous picture, representing the situation for the past 200 or 300 million years.

The conception of a homogeneous universe with a definite volume and definite contents seems moderately comfortable until we remember the red-shifts. The conception is derived from relativity, and relativity assumes that the universe will appear much the same no matter where the observer happens to be situated. Since the nebulæ appear to be rushing away from our particular position, they will appear to be rushing away from any other position in which an observer is located. This apparent anomaly is explained on the theory that the universe is expanding, The radius of curvature is a function of the time and is now increasing. The volume is increasing and the density is diminishing. The conventional analogy in two dimensions is again with the surface of a sphere, say a rubber balloon which is being inflated. From each point on the surface, all other points are retreating and, within certain limits, the farther away they are, the faster they recede.

The expanding universe, with its momentary dimensions as previously described, is the latest widely accepted development in cosmology. Various refinements as to the nature of the expansion have been discussed at length, but always with the aid of additional assumptions concerning the validity of which there is no consensus of opinion. Even the present position depends absolutely upon the interpretation of red-shifts as Doppler effects representing actual motions.

Further radical advances in cosmology will probably await the accumulation of more observational data—the elimination of more types of possible worlds. The data will come either from more detailed investigations of the present Observable Region or from a significant enlargement of the region itself.

The latter alternative will be achieved with the 200-inch reflector in course of construction for the California Institute of Technology, with the assistance and cooperation of the Carnegie Institution of Washington. This great telescope, in the hands of experienced research men in the two institutions, is expected to enlarge the available sample of the universe some ten times in a single step and will increase in a corresponding measure the chances that our sample is fair and significant.

I believe the 200-inch will definitely answer the question of the interpretation of red-shifts, whether or not they represent actual motions, and if they do represent motions—if the universe is expanding—the 200-inch may indicate the particular type of expansion.

This prospect is the climax of the story. Our present information concerning the universe is necessarily vague. It is new and raw and will mature only with time and continued study. The great significant feature is that the first steps have actually been achieved—that in our generation, for the first time, the structure of the universe is being investigated by direct observations.

SOME MORTUARY CUSTOMS OF THE WESTERN ALASKA ESKIMOS

By CLARK M. GARBER

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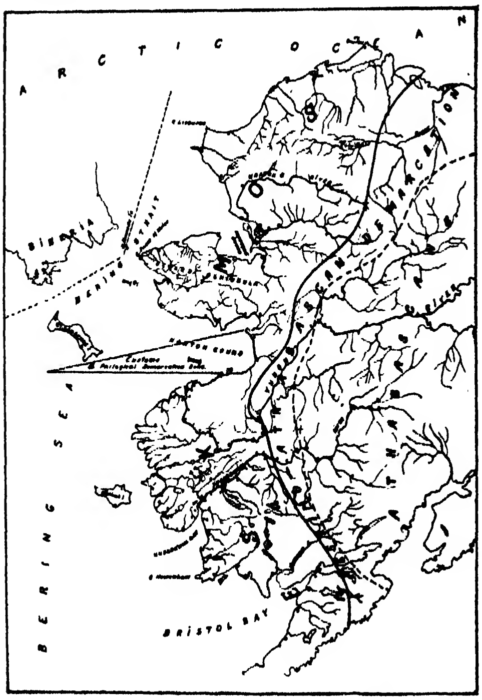
Although in recent years there has been considerable stimulation behind the archeological and anthropological study of the western Eskimos no ethnological and sociological investigations concerning the cultures of these people have been made since Petrof (1880) and Nelson (1877–1890). This article, therefore, has for its purpose the supplementing of any previous studies conducted along this line and is not intended as a criticism or correction of the results of any former ethnological investigations. The author has long ago recognized that the aboriginal peoples of western Alaska are rapidly becoming Americanized by reason of their increasing contacts with the white race. Hence, if much of this valuable information is to be preserved for the benefit of future generations, it must be done now. This dissertation is a part of the product of the author's eight years of study and experience during an intimate contact with these people. As indicated by the title of this article the present study will be confined to an examination of the mortuary practises which have been racial customs among the western Eskimos and in addition a few of the practises and customs which have an intimate bearing upon their mortuary rites. From the standpoint of pure ethnology and also ethnological archeology the burials, mortuary rites and memorials of the Eskimo people are fundamentally important to the broader and more general subject of Eskimo ethnology.

Since the time of Nelson's and Petrof's investigations among the western Eskimos great changes have taken place in their geographical distribution. The group or tribal boundaries given by Nelson can no longer be applied. Since the Americanization of Alaska began demarcation lines separating these people into tribes have become indistinct. Increased social contacts have caused intertribal and intervillage marriages, so that bloods have been pretty generally mixed. Where the Malmutes, Kuskokwagamutes, Ikogamutes or Nunivagamutes begin or end geographically would be a very difficult matter to determine. For the purpose of this study it is not necessary to make such fine distinctions, since the matter at hand depends to a greater extent upon custom and language grouping. Philologically the western Eskimo of Alaska can be divided into two major groups. The first group involves all Eskimo people inhabiting the western coastal belt—averaging two hundred miles in width—from the Alaska Peninsula to Norton Sound. The second group begins at Norton Sound and involves all Eskimo people living in a similar coastal belt from Norton Sound to Point Barrow. Within these groups can be found dialectic differences which in turn could be used for the basis of finer distinctions, yet they do not affect the custom grouping. This dialectical differentiation rather than customs differentiation was no doubt the basis upon which Nelson constructed his cultural classification.

By grouping the western Eskimos of Alaska according to their mortuary practises and customs we find that, not

unlike the linguistic grouping, two major groups prevail. The line of demarcation between the two major mortuary custom groups is, for this purpose, identical with that of the language groups. However, we must recognize that even this group classification does not imply such differences in individual or group characteristics as to lead the reader to believe that there are sharply defined tribes, such as are found among the American Indians. The death, burial, memorial and religious rites of these people are taken as the basis for grouping them according to their mortuary customs. There is no doubt that these two major mortuary and linguistic groups existed long before the white man established contacts with the western Alaska Eskimos. The line separating these groups is comparatively sharp, while the boundaries of the groups given by Nelson are rather indistinct.



Clark M. Garber

CUSTOM AND PHILOLOGICAL DISTRIBUTION OF THE WESTERN ALASKA ESKIMOS. 1932.

FIG. 1. GRAVE OF AN ESKIMO WOMAN OF KIPNAGAMUTE

HERE STARVING DOGS AND MARAUDING ANIMALS HAVE TORN THE GRAVE BOX OPEN AND HAVE MADE A GOOD MEAL OF THE CORPSE. SIGHTS LIKE THIS ARE COMMON IN THE COASTAL SECTION OF ALASKA BETWEEN THE YUKON AND KUSKOKWIM RIVERS.

And it is difficult to determine where one group began and another stopped, because of the gradual merging of each group with its neighboring groups. In this discussion I will therefore refer to these two groups as the northern and southern groups of western Alaska Eskimos.

In his primitive state the Eskimo devotes his life, not to the accumulation of a large amount of worldly goods and the preparation for death, but to the proposition of making his existence on earth just as pleasant and effortless as possible. Not until he arrives at death's door does he expect to attain happiness. The Eskimo after-life is available to good and bad alike, for in his religion there is no eternal punishment for the wicked or evil. Closely associated with his primitive religion are the customs which he has developed in the matter of preparing the dying and the dead for proper entry into the world of happiness beyond.

Causes of Death

The white man has found an easy way to account for an unaccountable death by laying the cause to complications. To the Eskimo this simple explanation would not suffice. There are many causes of death among primitive peoples. Some they understand because they are visible, but the invisible mysterious deaths are always attributed to the displeasure of the spirits. The Eskimo world is full of spirits. All animate and inanimate things have them. There are spirits of the living and spirits of the dead.

The causes of death may, for the purpose of this discussion, be classed as natural and mysterious or visible and invisible. The natural causes of death are war casualties, domestic quarrels, accidents, conflicts with wild beasts, suicide and old age. The mysterious causes of death are those due to sickness, insanity, childbirth, evil spirits and disappearance.

In the cases of sudden death no preparatory rites could be accomplished. Even in cases of death from old age sudden demise was in ancient days expected. In fact, it was a social custom of economic compulsion, when advanced years brought on the inability to contribute to the support of the household, that the life of the aged should be snuffed out by the knife in the hands of some relative or shamin. This custom was not practised at all times. Years of famine and starvation were the compelling economic cause. Then it became necessary to restrict the consumption of foods to the able-bodied. Male children were also favored in this economic elimination of unnecessary food consumers. All mortuary rites attending sudden death were, of necessity, conducted subsequent to death, *i.e.*, no preliminary preparations could be made.

It was the mysterious causes of death that permitted actual preparations before death. In the case of disease it was believed that the person afflicted had displeased one or more of the spirits. If the magic, incantations and physical ministrations of the shamin or witch doctor failed to effect a cure, then it was decided that the evil spirits infesting the sick person could not be appeased nor could they be forced to leave the body.

FIG. 2. ILLUSTRATING THE METHOD OF INTERMENT ON BERING STRAIT
THE CORPSE HAS BEEN WRAPPED IN A WALRUS HIDE AND THEN PLACED IN A CRUDE COFFIN MADE OF ROUGH HEWN PLANKS. BEFORE THIS GRAVE COULD BE EXPOSED IT WAS NECESSARY TO REMOVE A QUANTITY OF LARGE ROCKS WHICH HAD BEEN PLACED ON TOP OF THE GRAVE AS A PROTECTION AGAINST PREDATORY ANIMALS.

FIG. 3. ABOVE GROUND BURIALS FOUND AT AKOOLARAK ON THE LOWER KUSKOKWIM RIVER. EACH BOX CONTAINS THE CORPSE OF AN ADULT WHICH HAS BEEN JACK-KNIFED IN ORDER THAT IT MAY OCCUPY THIS SMALL SPACE. THE BOXES ARE MADE OF ROUGH HEWN PLANKS FASTENED TOGETHER WITH WOODEN DOWELS AND RAWHIDE LASHINGS.

The patient thereupon stoically resigned himself to his fate and preparations were made for his death. Should the shamin experience too many failures in his practise of medical rites, he was looked upon as a man of evil. This has been the cause of an early death for many a shamin. To-day the western Eskimo is treated for his ills by the white man's *yungchowista* (doctor), yet after fifty years of the white man's educative efforts they have little faith in the white man's medicine. I have witnessed them procure medicines from the white doctor, take this medicine directly to their shamin or *yungchowista,* who destroyed it or kept it for his own purposes, and ask their own conjurer of medicine to treat them for their ills.

The physical ministrations practised on the sick by the shamins very often were, unknown to them, the actual cause of the patient's death. I recall one case of this kind which I personally witnessed. In the village of Keengegan on Bering Strait a small boy had contracted pneumonia. The medicine woman of the village was called in to minister to the patient, contrary to my advice to the parents. After many feelings and manipulations of the child's body this authority on Eskimo medicine announced that the child's liver was very much enlarged. She then proceeded to reduce this enlargement by mechanical force, even against my vehement objections. The result was a serious pulmonary hemorrhage, which caused death in a very short time.

Lingering sickness very often resulted in sudden death. Among the northern Eskimos of western Alaska it was the custom to shorten life in cases of long sickness. This amounted to nothing less than deliberately killing the sick person. The act was usually performed by some close relative and was not committed unless the sick person was a great burden to the relatives. Thus we see an economic situation again dictating who shall live and who shall die. Although I did not witness such an act of mercy and economic adjustment I recall one case in which no doubt could remain in my mind that the act had been done. This was a case of a once famous hunter who had been brought to his bed of reindeer furs suffering from the white man's dreaded plague. For several weeks this man lived with his brother, growing weaker and weaker each day. On this occasion I came into the innie to bring comfort and medicine to the patient. His brother sat near him, whetting his hunting knife to a razor edge. Both knew the purpose of this preparation, yet they visited, conversed about many matters and even joked occasionally, but neither made any allusion to the contemplated act. On the following morning a cousin of the sick man came to me with the advice that the patient had died during the night. Upon my suggestion that I examine the body, consternation was plainly visible

on his face. This convinced me that the contemplated death pact had been carried out. But, since it was in fact an act of mercy and economic adjustment I did not deem it advisable to pry into the affair any further. In truth the confidence of these people would thereby be destroyed and I would gain nothing from their tight-lipped stoicism. The body was then clothed in new reindeer skin parka, new mukluks and new sealskin mittens, all of which had been made in preparation and expectation of this death. The coffin or box was built outside the innie and the body hoisted through the window or smoke hole in the top, after which it was placed in the box and the funeral rites begun.

Death of the Insane: Eskimo people have a great fear of an insane person. They believe that the spirits have all forsaken him and that he just wanders about aimlessly. It is also believed that evil spirits enter the body in which the good spirits will no longer live. For this reason it is thought that the insane person is just the same as dead, but that the spirits have left his body while he was yet alive. Violently insane persons were put to death quickly, since they were believed to be very dangerous. Others less violent were tolerated until a more opportune time or until they had committed some depredation that warranted quick destruction. In a village on the Seward Peninsula a man's brother-in-law had gone insane. This crazy person was tolerated about the innie and was even fed and slept in his brother-in-law's dwelling. However, one night before the household had retired, this insane man became violent and threatened to kill all members of the family after they were all asleep. His brother-in-law waited until the crazy man had fallen asleep in his bunk and then without the least compunction stabbed him to death. His body was then prepared for burial, but he must be buried without the embellishment of new clothing. The good spirits had left his body and would never return. No weapons, tools or implements could be placed in his grave, else he may run amuck and bring unhappiness in the next world.

One day (1926) I was very much surprised to receive the following letter from a man who lived near the Eskimo village of Ikpick.

Dear Garber:

You know my brother he crazy You say alright I shoot him.

Here we find a young man ready to carry out tribal custom long after he had established contact with white missionaries. There can be no doubt that he would have destroyed his insane brother had I but given my sanction to the deed. Fortunately the next traveler

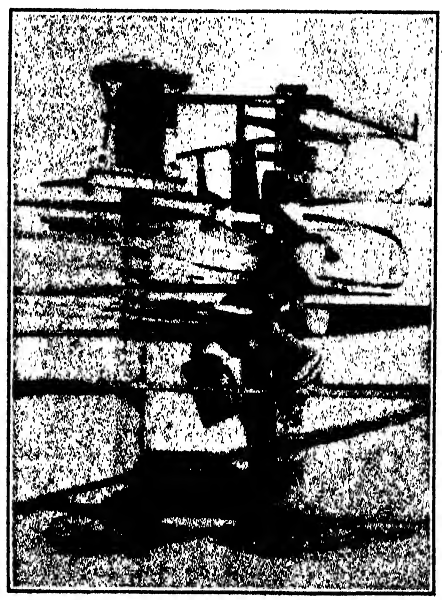


FIG. 4. ESKIMO BURIAL

AT THE VILLAGE OF KINAGAMUTE ON THE LOWER KUSKOKWIM RIVER. THE COFFIN IS PLACED ON THE GROUND BETWEEN THE POSTS WHICH SUPPORT THE PROPERTY OF THE DECEASED. NOTE THE MIXTURE OF PRIMITIVE WEAPONS AND TOOLS WITH THE MODERN ONES OF THE WHITE MAN'S MANUFACTURE.

FIG. 5. PORTION OF ESKIMO CEMETERY AT KEENGEGAN ON BERING STRAIT
HERE WE FIND THE GRAVES PLACED AMONG THE ROCKS ON THE MOUNTAIN SIDE. THE TOOLS, HUNTING GEAR, UMIAK AND KAIYAK FRAMES AND SOME TROPHIES OF THE HUNT HAVE BEEN STREWN ABOUT AND OVER THE BURIALS. IN THIS CEMETERY THE AUTHOR COUNTED MORE THAN EIGHTEEN HUNDRED VISIBLE BURIALS, WHICH ATTESTS THE STRENGTH AND SIZE ONCE ATTAINED BY THIS COLONY. INHUMATIONS WHICH HAVE DISAPPEARED FROM SIGHT BENEATH THE TUNDRA WOULD PROBABLY NUMBER INTO THE THOUSANDS.

brought word that the insane man had died a natural death during an insane fit. *Did he?*

If a person designates before his death just where he wishes his body to rest it is considered a very sacred duty on the part of the relatives to see that the dead man's wishes are complied with. Some have selected crevices in the mountain rocks, some designate the tops of peaks, some wish a particular plot of ground which has attracted them, and some choose to have their bodies rest in old family innies which are no longer used as dwellings. It is rather infrequent that the Eskimo selects his burial spot before death. The usual custom is to leave the matter for the relatives to decide. This results in the body being buried in the common burial ground.

Burial Rites

Among all the western Alaska Eskimos it is customary to remove the corpse from the innie on the same day that death occurs. If death occurs at night the body is removed from the dwelling at daybreak. In some instances, particularly to the south of Norton Sound, I have known the body to be kept until the second day after death before inhumation. This, however, is an exception rather than the rule. It is only under unusual circumstances that a corpse is kept over night. Such circumstances involve the making of the box, sending word to relatives or completing the new outfit of clothing for the corpse. The corpse is never taken out of the dwelling through the common entrance. In the case of an innie it is removed through the smoke hole or window in the top of the structure. If the deceased lived in a log cabin or other frame structure above ground the corpse is taken out through the window or a special hole is made in the roof for the purpose. Death in a snow igloo presents another problem, since there are no windows in this type of dwelling. In this case a couple of blocks of snow are removed from the wall near the ground and the corpse taken out through the resulting opening.

Death is usually attended by relatives and friends, who crowd into the small dwelling in such numbers that there is little space left for the dead or dying person. Mourning continues until the body is removed from the dwelling. This consists in loud wailing and moaning on the part of the relatives, but no tears of sorrow are shed. The reason why tears are not shed as a matter of sorrowful mourning for the dead is a religious one. After an Eskimo being has departed this world and comes into the next he must, before he can enter into the place of everlasting happiness, cross a river of tears. If relatives and friends of the dead shed tears of sorrow this river of tears will be swollen to such an extent that the dead person's spirit will be unable to cross and will wander about until the flood of tears subsides. The funeral rites of the western Eskimos are therefore seldom attended by the shedding of tears of sorrow. I have witnessed parents bury their children and children bury their parents without the least demonstration in the way of tears.

Among the western Alaska Eskimos to the south of Norton Sound there has developed a very peculiar and interesting custom of preparing the corpse for inhumation. This involves bringing the body into a jack-knifed position by drawing the knees up to the shoulders and placing the hands and forearms across the abdomen. The head is then forced down so that it rests upon the knees. In this position the corpse is wrapped in its death shroud, consisting of reindeer or sealskins and is then bound tightly with rawhide lashings. When the body has cooled and the muscles have hardened the lashings are removed and the body introduced into the box that has been built for it. Relatives are not allowed to prepare the corpse for burial, unless it be an extreme circumstance that makes such action necessary. The box is made by the men of the village, and in case the corpse is a male the men of the village dress it for burial. Up to the time of this writing the author has not succeeded in his efforts to determine the factors responsible for the development of this peculiar type of burial. One of several factors or even a combination of these factors may be the underlying cause. Of these religion, economics, social custom and supersti-

FIG. 6. ESKIMO BURIALS AT TANUNAK ON NELSON ISLAND

THE GRAVES BEARING POTS, KETTLES, BUCKETS, PANS, LADLES, ETC., ARE THOSE OF WOMEN AND ARE NOT HARD TO DISTINGUISH FROM THE GRAVES OF MEN, WHICH BEAR WEAPONS, HUNTING EQUIPMENT, TRAIL EQUIPMENT, SLEDS AND TOOLS.

tious fears may be mentioned. If the jack-knife burial could be attributed to any of these factors we would yet have to find the reason. Underlying any primitive custom there is a reason for its development. This reason may be lost in antiquity, so that the Eskimo of to-day would know no more about it than the ethnologist himself.

In the coastal section to the south of Norton Sound driftwood has frequently been so scarce that there has not been sufficient to provide material for the making of coffins. In this case the jack-knifed corpse is simply placed in a sitting position leaning against a stake placed at its back. Here the corpse is left to sit on the tundra, where it may furnish many good meals for the starving dogs and predatory animals. In some cases I have observed these tundra burials entirely exposed, with the exception of a few stakes driven into the ground around them or some of the deceased's implements scattered over them. Of course this arrangement affords no effective barrier to wolves or starving dogs. Even the wooden coffins have at times been clawed and chewed apart in order that savage animal hunger may be satisfied. Fig. 1 illustrates the grave of a woman which has been ravaged in this manner.

North of Norton Sound we find the preparations of the body for burial very similar to those used by the Eskimos to the south. However, there is one great difference in the preparations of the dead for burial between these two groups of western Eskimos. The Eskimos in the northern section do not jack-knife the corpse for burial. Here the body is dressed in new fur clothing and wrapped in a walrus hide or reindeer skin. Then it is laid at full length upon a rough hewn plank. This plank supporting the body is then carried or hauled to the burial grounds where it is deposited upon the ground—sometimes a niche is formed with loose rocks for this purpose—with the feet to the east in order that the departing spirit may face the rising sun (Fig. 4). A plank is then placed on each side of the corpse and another over the top, thus forming a long rectangular box with open ends. In some cases these open ends have been fitted with end boards fastened in with dowels and lashings. In others large flat stones have been placed over the ends. The grave is now covered over with rocks to prevent marauding animals from getting at the corpse. On Bering Strait I have found graves made of shallow stone walls, in which the corpse was placed without the protection of a wooden coffin. In this case large flat rocks were placed across the walls as a covering or lid and then a mound of loose rocks built over the entire grave. This method of interment was probably developed much earlier than the coffin method.

Near the village of Tanunak on Nelson Island the author discovered two different types of graves, leading to the belief that two separate peoples had established contact at this place. Investigation of the matter has brought to light the information that a group or hunting party of Innuit landed on this island many years ago and established a colony here in close proximity to the Yuits, who were the native inhabitants of the island. Examination of the graves of these people and their contents in the way of implements and ornaments revealed a very close association or resemblance to the Bering Strait or St. Lawrence Island Eskimo type of burial. Here was found the full length burial of the Seward Peninsula and Kotzebue Sound Eskimos closely associated with the jack-knife burial characteristic of the Nunivak and Nelson Island Eskimos. Further investigation disclosed that a strange people were apparently lost in a storm at sea and were driven ashore on this island. Not knowing where they were or how to return to

their own people they established a colony near the present village of Tanunak. These people called themselves Innuit, which is the Eskimo term for "the people" of Bering Strait. They could not converse with the native Eskimos of Nelson Island and consequently mingled but little with other peoples. Eventually the colony died out, and now all that is visible are some of the graves and the old village site.

Should an Eskimo person die while living in a temporary camp or summer colony away from the main village his body is not taken to the main village for burial. His grave is prepared right at the camp and often within a few feet of the innie or tent. For this reason the entire western coast of Alaska and the shores of the lakes and streams will be found dotted promiscuously with burials.

The practise or custom of burying the dead in wooden boxes has no doubt had its beginning in the proximity of the Alaska Peninsula. A study of the burial customs and methods of the western Alaska Eskimos reveals a gradual dwindling of this practise as we follow the western coast of Alaska from south to north, and when we arrive as far north as Bering Strait or Kotzebue Sound we find that it is only within comparatively recent years that wooden coffins have been made for the dead. Even now among the northern Eskimos of Alaska we may find an occasional exposed burial, *i.e.*, burial without a coffin, particularly where driftwood is short or absent and there is nothing from which to make the box.

Closely associated with their primitive religion the western Eskimos have developed certain burial rites and definite procedures involving the burial of the dead and the respective behavior of the living thereafter. Those living to the south of Norton Sound believe that the spirit of the male dead remains with the body for a period of five days. For the females this period is four days. Subsequently, the spirit leaves the body and wanders at will, returning to the body if it so desires or immediately crosses the river of tears into the land of happiness. During this five- or four-day period no person is allowed to do any work with sharp edge tools, because the

FIG. 7. OLD BURIALS AT THE VILLAGE OF QUIGILLINGOK

COMPARE THESE GRAVES WITH THE ONE ILLUSTRATED IN FIG. 8, WHICH IS A MORE RECENT BURIAL IN THE SAME VILLAGE.

FIG. 8. A WOMAN'S GRAVE IN THE VILLAGE OF QUIGILLINGOK. THIS BURIAL IS ESTIMATED TO BE MORE THAN ONE HUNDRED YEARS LATER THAN THOSE IN FIG. 7. REGARDLESS OF THIS APPARENT DIFFERENCE, THE BURIAL CUSTOMS AND RITES HAVE REMAINED VIRTUALLY THE SAME.

spirit of the dead person may be hovering close and consequently be injured. For a period of one day after death occurs none of the relatives of the deceased are permitted to do any work at all. They must just lounge around the innie and keep busy at doing nothing. To the north of Norton Sound the same periods of abstinence are observed, but there the time involved is five days for the male and three for the female. Although this period of abstinence may vary considerably throughout the area covered by this discussion it is fundamental that the custom of observing them prevails among all western Alaska Eskimos. In some villages certain foods may not be eaten by the relatives of the dead during this period of abstinence. These foods in particular were those for which the deceased had a special fondness.

Transportation of the dead must be accomplished after the dictates of custom and taboos. On the Kuskokwim River a corpse can not be transported on the river, either by boat or by sled. To desecrate this custom would incur the wrath of the fish spirits, and as a result the fish would not come into the river the following season. This is a general taboo among all the villages to the south of Norton Sound. Should a person drown, his body must be recovered, else there will be no run of fish the next summer. With the northern group of Eskimos, particularly in the Bering Strait villages, the dead must not be transported to the burial ground in a roundabout way. The corpse must be taken over the shortest route possible between the death house and the grave.

It has been a common custom among all western Eskimos to make offerings of food to the spirit of the dead. This is done immediately after the body has been placed in its grave. The food offerings consist in choice morsels of all foods common to the particular locality in which the deceased has lived. Seal meat, walrus meat, reindeer meat, muktuk, dried fish, clams, berries and other choice dishes may be offered to the spirit of the dead. These offerings are made only by the surviving relatives of the deceased. In some localities it is the practise for the relatives to carry the food offerings to the burial place and after placing generous portions on the grave they would assemble about the grave and feast with the spirit of the departed.

Types of Graves

On the lower Yukon River, about Norton Sound and on the lower Kuskokwim River, it is a common thing to see some of the graves built above ground. What belief or superstition gave rise to this special type of grave will probably never be known, but was possibly done to protect the corpse from marauding animals. Inquiries made

among the old men, shamins and witch doctors of the villages fail to throw any light whatever upon the origin of this type of burial. The coffin or box is generally supported by a framework of posts, which are notched in the top to support cross pieces. However, in a few instances I have observed the stumps of trees used for this purpose. In this case the trunk portion of the stump is placed in the ground and the roots are above ground. The roots are then cut down to make a tablelike structure on which the coffin is placed (Fig. 3). The coffin is made of hewn planks fastened together by dowels and rawhide lashings. In the box with the corpse were placed all the small trinkets, extra ornaments, tools and weapons of the deceased. In the case of a woman the box contained her sewing kit, skinning and tanning implements and any other small articles which may have become a part of her household functions. Her beads, ear rings, bracelets and other ornaments adorned her body, having been placed there at the time of death. All the property of a movable nature belonging to men, women or children was placed within or upon their respective graves. It is only in cases where the deceased has been insane, an evil person, has died from some loathsome disease, is stillborn or has accumulated very little property that the graves are devoid of these objects.

The placing of the deceased person's property in and on his grave has a close association with the religious philosophy of the Eskimo. As mentioned in a former paragraph, all things have spirits; hence, when a man dies, especially his hunting gear, camping equipment and tools must accompany him to the grave in order that his spirit, on entering the world of happiness, may be helped by the spirit of the rifle, harpoon, spear, kaiyak, umiak, sled, knives, etc. Therefore we find as illustrated in Figs. 4, 5 and 6 all the movable property of the deceased placed upon his grave. In some cases I have found small objects, such as stone knife blades, adze blades, spear and harpoon points and much ivory buried beneath the coffin. Some are placed within the box, while some, especially the larger objects, are strewn about over the top of the grave. This is the custom with the Eskimos north of Norton Sound. The Eskimos south of Norton Sound place the coffin on the ground and on each side of it set a post in the ground. In some cases only a single post is used. Upon these posts are fastened the various items belonging to the deceased.

Near the village of Quigillingok at the mouth of the Kuskokwim River are found two different types of burials. The difference in these burials does not imply a change in custom between the

FIG. 9. MEMORIAL FIGURE PLACED OVER A WOMAN'S GRAVE AT THE VILLAGE OF KINAGAMUTE. NELSON HEARD ABOUT THESE MEMORIALS AT THE TIME OF HIS ETHNOLOGICAL WORK AMONG THE WESTERN ESKIMOS BUT NEVER HAD THE OPPORTUNITY TO INVESTIGATE AND EXAMINE THEM.

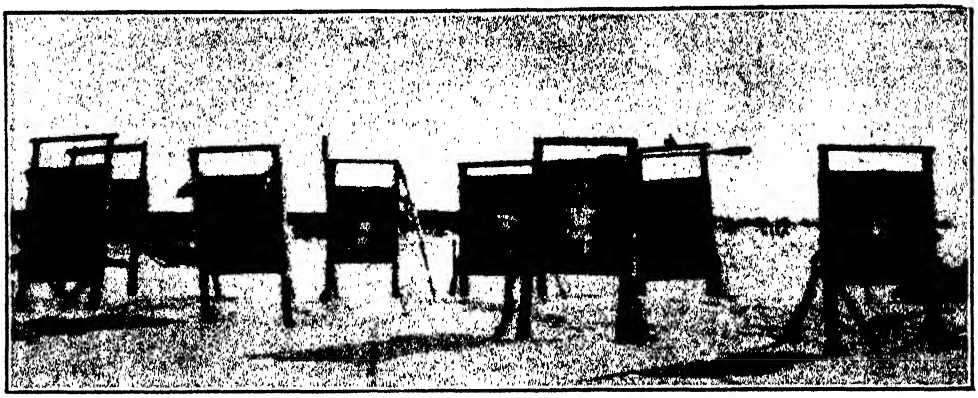


FIG. 10. GROUP OF ESKIMO GRAVES AT KINAGAMUTE ON THE LOWER KUSKOKWIM RIVER. THESE ARE MEMORIAL FIGURES CARVED BY RELATIVES OF THE DECEASED.

times of the two interments. It portrays a change in the economic factors controlling burials at these two times (Figs. 7 and 8). The graves made of rough logs represent burials which are estimated to be more than a hundred years older than the other in which the white man's cut lumber has been used. In both burials the corpse has been jackknifed before interment and the property of the deceased has been placed within and upon the graves in the customary manner. Making the box from the white man's cut lumber has proven to be both a labor-saving and time-saving proposition and yet effects the inhumation in strict accord with customs which have prevailed for many generations. Fig. 7 illustrates a grave in which the coffin is made of logs split in half and mortised at the corners. The flat sides of these hewn slabs form the inner surfaces of the box.

At the village of Kinagamute on the

FIG. 11. MEMORIAL FIGURES ERECTED OVER NATIVE GRAVES AT THE VILLAGE OF NUNACHAGAMUTE

lower Kuskokwim River we find a peculiar and most interesting type of burial. At no other place among the Western Eskimos of Alaska do we find memorial grave markers such as these. Two posts are set at the head of the grave about three feet apart and extending to a height of six feet above the ground. Beginning about thirty inches from the ground the two posts are boarded up to within one foot of the tie beam which joins the posts across the top. At the top of the boarded section there extends a roof or canopy for about two feet at right angle to the upper margin of the boarded surface. Under this canopy and fastened to the boarded surface is found a human figure. The head is carved from wood and is made in an oval shape with ivory or bone insets for eyes and mouth. The hands are also of wood and frequently hold some object, such as a spoon, knife, sewing kit, etc. The torso is covered by fur or cloth garments, adorned with pendants, buttons, etc. This is, in all probability, the type of burial mentioned by Nelson in the Eighteenth Report of the Bureau of Ethnology in which he states, "I was informed that the graveyards of the villages on the Kuskokwim, below Kolmakof Redoubt, are full of remarkable images of carved wood. One was described to me as being roofed with wooden slabs and consisted of a life-size figure, with round face, narrow slits for eyes, and four hands like a Hindoo Idol" (Figs. 9 and 10).

At Nunachagamute, a village located in the flat tundrous country between the Yukon and Kuskokwim Rivers, will be found burials very similar to that described in the preceding paragraph. In these burials not all the figures are mounted on the canopied frame (Fig. 11). The two figures with outstretched arms have their base or support in the ground. The figure at the right is adorned with a bead necklace, supports in one hand an ivory snow knife and in the other hand a modern kitchen knife. These wooden figures are not intended to portray the physiognomy of the deceased person. They are made as me-

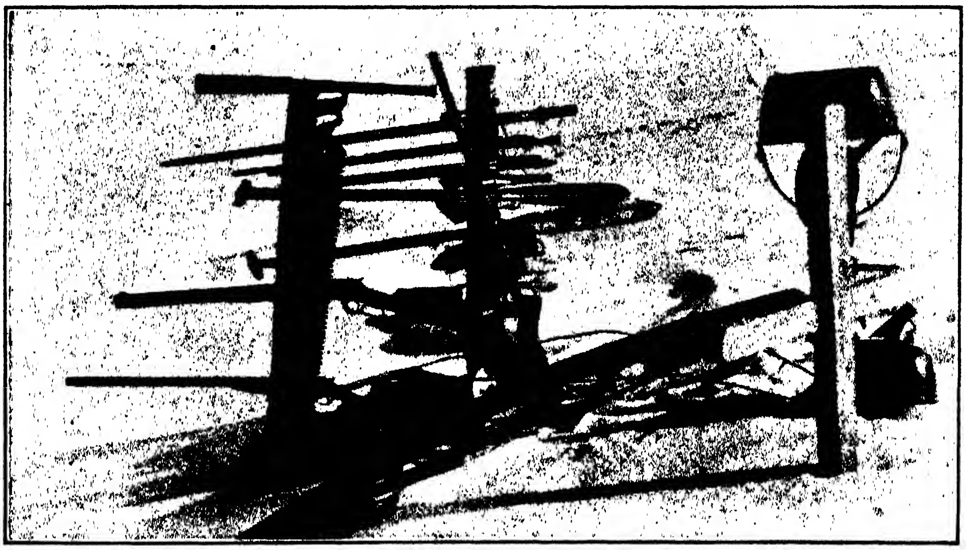


FIG. 12. TYPICAL BURIAL OF THE ESKIMOS SOUTH OF NORTON SOUND
THE MIXTURE OF NATIVE AND WHITE MAN'S IMPLEMENTS MARKS THE TRANSITION OF THE ESKIMO FROM THE PRIMITIVE TO THE SEMI-CIVILIZED STATE. A BURIAL OF THIS KIND REPRESENTS A CONSIDERABLE ECONOMIC LOSS TO THE CHILDREN OF THE DECEASED.

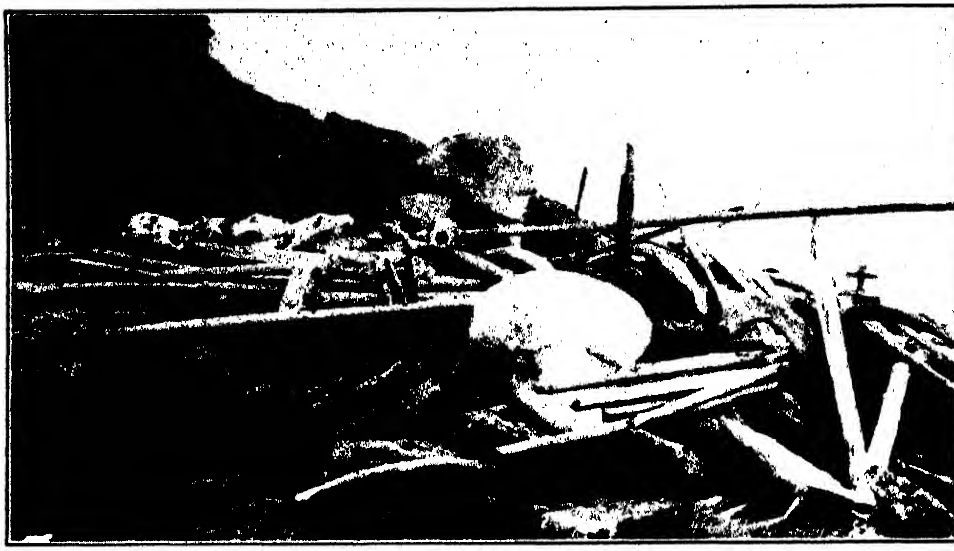


FIG. 13. TYPICAL BURIAL OF THE WESTERN ESKIMO NORTH OF NORTON SOUND

THIS IS THE GRAVE OF A FAMOUS I UNTER. HIS SEPULCHER IS STREWN WITH TROPHIES OF THE HUNT AND ALL HIS PROPERTY.

morials to the dead and have the same purport as one of the white man's tombstones. The carving is done by relatives of the dead. It is not always done immediately after death, but may be done at any time. One instance has come to my attention in which one figure was carved by the husband of a deceased woman. This figure was mounted over the grave shortly after inhumation. About fifteen years later the little son of this man and wife had grown up and desired to erect a memorial to his mother. He therefore carved his own memorial figure and placed it upon his mother's grave along with that of his father.

In the typical Yukon-Kuskokwim burial we find posts erected beside the grave, and on these are placed all items of property which belonged to the deceased. This typical burial is well illustrated in Fig. 12. A mingling of Eskimo and white man products is visible. The coffin, which rests on the ground between the posts, is almost covered with snow. It may be interesting to the reader to know that this grave bears more than four hundred dollars worth of guns, tools and other wares figured at prevailing Alaska prices. The white cross indicates that the man's wife or daughter has come under the influence of the missionaries, yet this influence was apparently not strong enough to overcome the customs of past generations. Perhaps the white man's religion is not right, so they think that the pots, kettles and pans had better be put on the grave to make sure that the spirit of the dead will not want in the next world.

Let us now examine a typical grave of the northern group of western Eskimos (Fig. 13). This is the grave of a famous and once powerful hunter. His trophies adorn his sepulcher. The shoulder blades of two large and one small whale and nine polar bear skulls are visible to attest the prowess of this departed chieftain. His umiak and kaiyak frames are scattered over the grave. His hunting equipment, weapons, tool kit and many other items of his

property are found beneath the stony coffin. This grave is located near the village of Keengegan on Bering Strait. Surely his fame and power will continue with his spirit into the next world. There the spirits of the weapons he has used and the animals he has slain will help him to attain eternal happiness.

Influence of Religion

In recent years the influence of religious workers among the western Alaska Eskimos has had a decided effect upon the mortuary rites and practises of these people. No less than eight religious organizations are represented by missionaries among the western Eskimos. Of these the Greek or Russian Orthodox church has probably had a longer and more lasting influence. But since the Americanization of Alaska began and since the Russian church no longer supports a paid clergy in Alaska, there is a perceptible weakening of the Russian Orthodox influence. On the lower Yukon and Kuskokwim Rivers will be found Russian Orthodox churches maintained by the Eskimo people and presided over by Eskimo priests (Figs. 14 and 15). With the coming of the white man's religion the Eskimos are slowly but surely being weaned away from their racial mortuary customs. Those who have succumbed to the new religious influence will be buried underground, and the cross of the Orthodox or Christian church will appear as their only grave memorial. The white man's religion has not reached all the western Eskimos. In some of the isolated sections they will be found, not only living in their primitive state, but practising the customs of their forefathers. Among these remaining primitive settlements of Eskimos the ethnologist, anthropologist and archeologist may still find a virgin field for their endeavors.

Group Burials

The proposition of burying a number of people in a common grave has never been adopted as a general practise or custom among the Eskimos. There are, however, in the Bering Strait region some cases in which this system of burial has been utilized. On the top of

FIG. 14. RUSSIAN ORTHODOX CHURCH AT THE VILLAGE OF QUITHLUK ON THE LOWER KUSKOKWIM RIVER. THIS CHURCH STANDS IN A SETTLEMENT SURROUNDED BY MISSIONARIES OF THE CHRISTIAN RELIGION, YET ITS FOLLOWERS CLING FAITHFULLY TO THE RELIGION GIVEN THEM BY THE RUSSIANS.

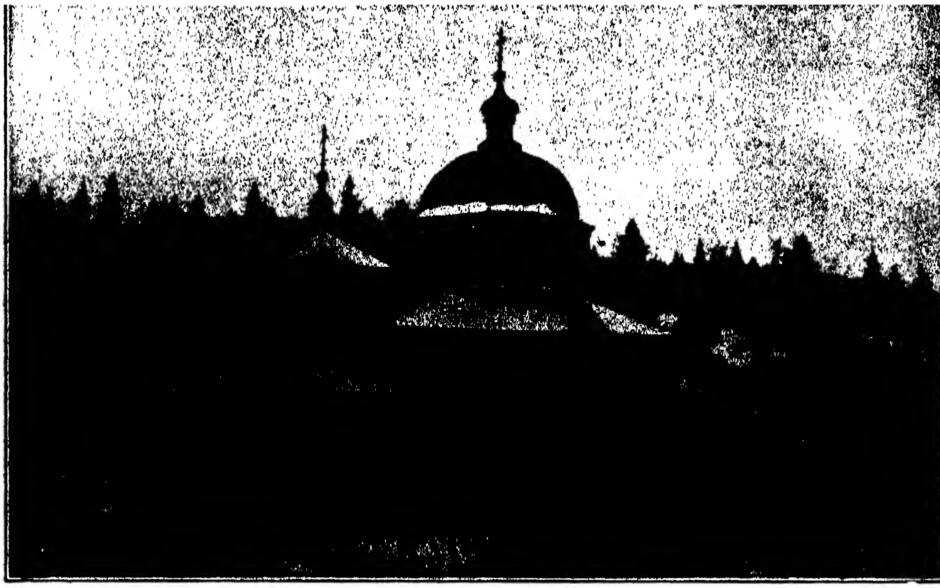


FIG. 15. RUSSIAN ORTHODOX CHURCH AT RUSSIAN MISSION ON THE LOWER YUKON RIVER. BUILT MANY YEARS PRIOR TO THE PURCHASE OF ALASKA BY THE UNITED STATES, THIS CHURCH REPRESENTS ONE OF THE MOST INTERESTING RELICS OF RUSSIAN DAYS IN ALASKA. RUSSIAN MISSION WAS AT ONE TIME A STRONG RUSSIAN POST SITUATED ON THE OLD OVERLAND TRAIL FROM ST. MICHAEL TO ILIAMNA BAY. SINCE THEN THE ESKIMO PEOPLE HAVE DECREASED IN NUMBERS UNTIL HARDLY ENOUGH NOW REMAIN TO CONDUCT THE ORTHODOX SERVICES IN THE OLD CHURCH.

a mountain ridge back of the village of Keengegan I have observed (1926) several large rock mounds which were approximately twenty feet in diameter. The rocks in these mounds were rather uniform in size, none of them being larger than one man could carry. This fact led me to some speculation as to the contents of the mound and how it may have originated. Believing that there may be some special type of burial hidden beneath these piles of rock I decided to investigate them thoroughly. The results more than justified the many hours of labor, for in the bottom of the first mound excavated were found five skeletons. Now before disturbing these remains a peculiar situation was observed regarding the burial. The bodies had been placed in the grave, not in parallel arrangement, as one would suspect, but in a haphazard pile. Examination of the skeletal remains disclosed the fact that they were warrior dead. In two of them flint arrow points were wedged between the rib bones and in another the skull had been punctured by a bullet which yet remained within the cranium. From this grave much war material was collected for further study. Later it was learned from the old men of the nearby village that these rock mounds contained the bodies of enemy warriors who had been killed in battle. This, no doubt, accounts for the disrespect accorded them by burying them in a haphazard heap. This is the only deliberate group burial which I have been able to locate in all the Eskimo burials which it has been my privilege to examine. However, I am informed by the Eskimo people that such burials also exist at East Cape, Siberia, and on Diomede and King Islands.

There is another type of group burial which may be classed as an involuntary

group inhumation. These may also be called epidemic group burials. The Eskimo population of Alaska has suffered much on account of famines, epidemics of smallpox, measles, influenza and other contagious diseases, until at the present time the actual Eskimo population of Alaska is only about one fourth the population of pre-Russian days. Epidemics caused deaths by the wholesale. Whole families and even entire colonies were wiped out. Many times families were trapped in their innies by these epidemics and there they perished. Fig. 16 shows the site of an Eskimo village near Cape Prince of Wales. This village of more than sixty people was entirely wiped out by the influenza epidemic of 1918. When death came no friends or relatives remained to care for the bodies of the dead. Their underground dwelling or innie became their grave. As years pass by these innies decay, the sod roof falls in, and an effectual underground group inhumation is produced.

Archeological Importance

The archeologist will find Eskimo burials equally as important as village ruins. While village sites and remains will be visible for a much longer time, the Eskimo grave contains a much greater store of archeological and cultural treasures. By reason of the fact that Eskimo burials of the past were surface burials their disintegration takes place very rapidly. Soon the tundra vegetation has covered them entirely, so that they may be virtually lost for all time. Occasionally these old burials may be identified by small mounds. Sometimes small pieces of hand-worked wood may be found on the surface, indicating that burials may be found nearby. The burials and village sites which fall within the memories of the present generation of Eskimos are of little value to the archeologist, who is interested in ancient cultures. But, to the ethnological archeologist these burials, even though they are no more than one hundred years old, hold a vast store of ma-

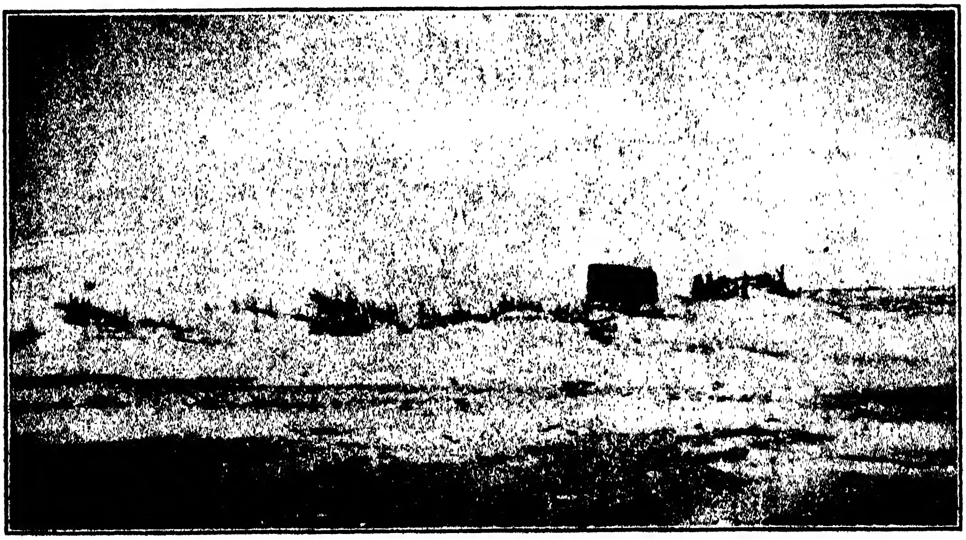


FIG. 16. POOLUZOK, AN ESKIMO VILLAGE ON BERING STRAIT

This colony, which numbered more than sixty people, was entirely wiped out by the influenza epidemic of 1918. Whole families are buried within their innies, which have caved in by decay.

terials and valuable information. The author has frequently discovered such old and forgotten sites through the legends and stories of the Eskimo people. Had we some means of discovering burials and village sites of a thousand years ago, yes, two thousand years ago, then our cultural determination of Eskimo sources and racial history would be greatly facilitated.

Eskimo burials and ruins which lie within the frequented lanes of travel are now being stripped of their archeological specimens by curio seekers, who do not appreciate the value of sequence and association in the collection of this valuable material. True, much of it reaches our museums, but even there its status can be nothing more than an Eskimo curio collection. Eskimos are thereby encouraged to make these excavations and sell the specimens which they find to the traveling public. Fortunately, their superstitious fears of the shades of the dead keep them from destroying their burials, and they feel that the white man who will face the wrath of the spirits to acquire curios from the graves is indeed a brave man. Of course, the ethnologist may draw many inferences from a collection of Eskimo curios which would supply him with indirect evidence concerning the manufacture and use of the various instruments and may even infer certain things to be true about the people who made and used them. So many erroneous conclusions have been drawn from such miscellaneous collections that I have come to favor direct evidence and information as the only reliable method of determining the facts about native peoples who are still existing. One year of life in intimate contact with a primitive people is worth more than ten years of perusing a conglomerate collection of curios, in so far as accurate ethnological data are concerned.

THE EXPLORATION OF THE FREE ATMOSPHERE

By LOUIS P. HARRISON
U. S. WEATHER BUREAU

THE first and almost unheralded ascent of Professor Auguste Piccard in a balloon to a height of about 15,780 meters (51,770 ft.) on May 27, 1931, broke upon an astonished world and brought to the attention of the public the mysterious stratosphere. Since that time not less than five similar ascents have been made, with new and greater ones projected for the future. While the results of these aerial voyages high into the atmosphere disclosed much that was new, especially for the student of cosmic rays, the major results ascertained had long been known to the meteorologist, thanks to the means evolved more than a quarter of a century ago. It is therefore well to indicate at this time the early history and development of the principal methods hitherto employed for the exploration of the free atmosphere, the more important facts regarding our airy medium which these methods revealed and finally the prospects for new advances which the future holds in store for the science of meteorology.

EARLY HISTORY AND DEVELOPMENT

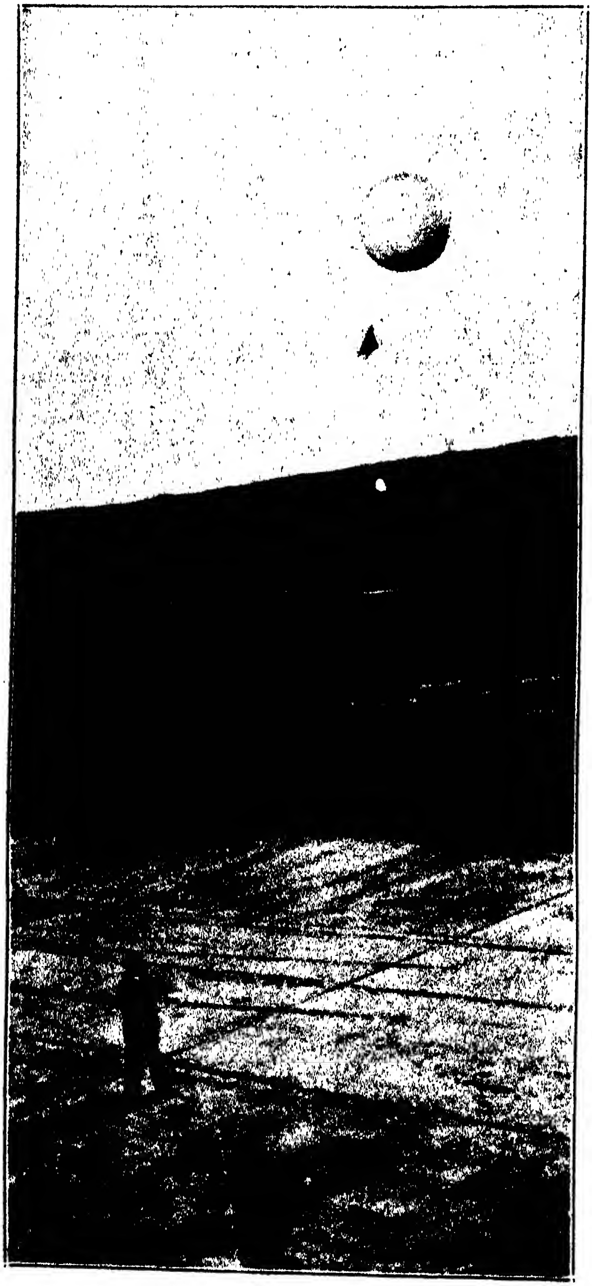
The first really important advance in the study of the upper atmosphere was the result of the famous experiment conducted on September 19, 1648, by Pascal's brother-in-law, Perier, who carried a Torricellian tube to an elevation of 1,460 meters (4,790 ft.) up the Puy de Dôme, one of the highest mountains in Auvergne, for it proved conclusively that the pressure of the atmosphere decreases as one ascends in it, and hence that it must be regarded as a fluid having weight and an upper limit.

The next important step in this field was not possible until after the thermometer, devised originally about 1597 by Galileo in the form of a thermoscope, had been brought to a form which gave comparable readings. This occurred during the period approximately between 1650 and 1750, so that following the middle of the seventeenth century it was not uncommon for expeditions led by scientific philosophers in various parts of the world to make ascents of the mountains for the purpose of observing the change of the barometer and the temperature of the air with height.

Toward the end of the eighteenth century, especially following the publication of the masterly *"Essai sur l'hygrometrie"* by the Swiss geologist and physicist, de Saussure, in 1783, observations of the relative humidity were also made on these expeditions, usually employing for this purpose a hygrometer made of specially prepared hair which increased in length with increase in humidity and *vice versa*.

Thus by the close of the first third of the nineteenth century, the mountain observations of such men as Bouguer, H. B. de Saussure, Deluc, Humboldt, the great traveler and naturalist, and others, had shown that the temperature of the air fell with height, on the average, at a rate of about 1° C. per 185 meters, (0.3° F. per 100 ft.), varying with season, time of day, etc. The observations also showed that the moisture content of the air diminished with

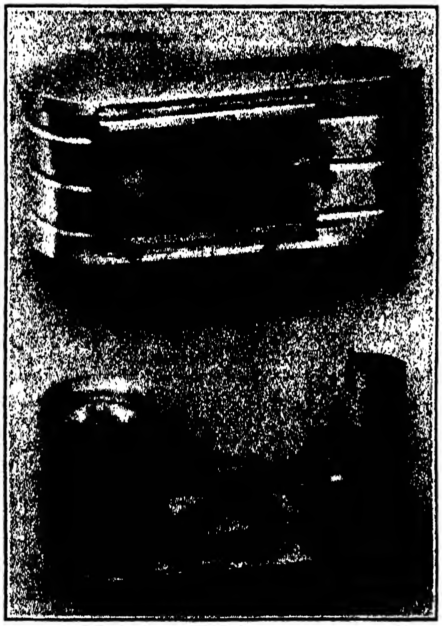
height, while samples of air taken at various heights had shown that the concentrations of the other known constituents of the air were essentially constant. Furthermore the law in accordance with which barometric pressure must fall with height and also the correct means for measuring heights in the atmosphere from barometer and temperature observations became known after the publication by Laplace of his great work, "Mécanique Céleste." Finally it was also known that winds generally increase with height and that there were ascending and descending currents in the atmosphere, partly from the study of clouds, which was especially stimulated through the scientific classification thereof by Luke Howard in 1803. However, the information we have just outlined formed nearly the entire store of enlightenment on the subject of the upper air available in the period in question, and moreover had the limitation that it was largely based on mountain observations which did not extend to great heights and were not wholly representative of conditions in the free air.



LAUNCHING A SOUNDING BALLOON

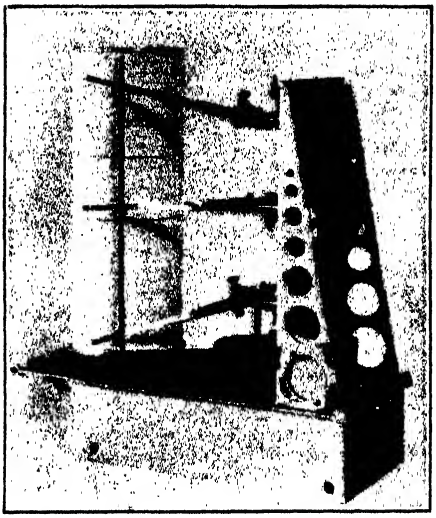
New and more potent methods of investigation had in the meanwhile been developed, for on June 5, 1783, the brothers Montgolfier at Annonay near Lyon in France launched their first free balloon in public, using hot air to give the necessary buoyancy, while by November 21 of that year Pilâtre de Rozier and the Marquis d'Arlandes were carried aloft in a free hot-air balloon and, on December 1, the physicist Charles, accompanied by one of the brothers Robert, who had constructed the envelope, ascended in a hydrogen-filled balloon near Paris to a height of about 2,000 feet, remaining in the air for

about two hours. The latter took with them a thermometer to measure the temperature of the air and a barometer to measure the height. A second flight made on the same day by Charles alone reached an elevation of nearly 9,000 feet. The first scientific balloon ascent was made from London on November 30, 1784, by Dr. John Jeffries, a native of Boston, Massachusetts, living in England. He carried with him a barometer, a thermometer, a hygrometer, an electrometer, a mariner's compass and six glass-stoppered bottles filled with distilled water. The bottles were emptied at various heights and sealed; and the



SOUNDING BALLOON METEOROGRAPH

OF THE FERGUSSON PATTERN, USED IN THE UNITED STATES; AN INSTRUMENT WEIGHING ONLY 200 GRAMS (0.44 LB.) AND DESIGNED TO GIVE A CONTINUOUS RECORD OF THE BAROMETRIC PRESSURE, TEMPERATURE AND RELATIVE HUMIDITY OF THE FREE AIR WHEN CARRIED ALOFT BY A SOUNDING BALLOON. *Below:* INSTRUMENT PROPER SHOWING SMOKED-ALUMINUM RECORD SHEET ON LEFT. *Above:* ALUMINUM PROTECTIVE COVER FOR INSTRUMENT.

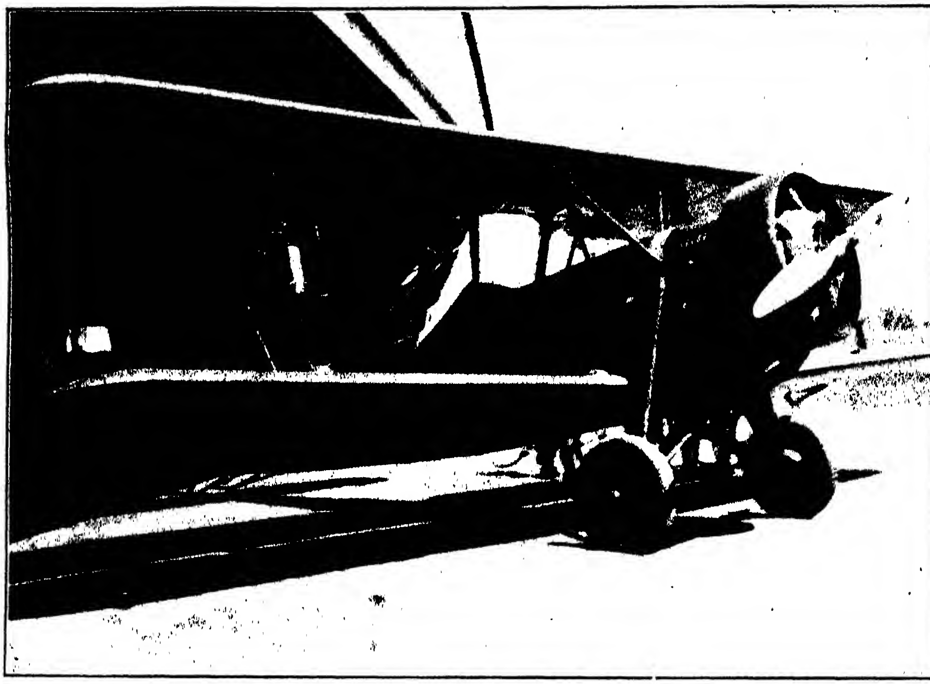


SIDE VIEW OF THE FRIEZ TYPE AERO-METEOROGRAPH

WITH PROTECTIVE COVER REMOVED. AN INSTRUMENT CARRIED ON WEATHER BUREAU OBSERVATION AIRPLANES TO MEASURE AND RECORD THE TEMPERATURE, RELATIVE HUMIDITY AND BAROMETRIC PRESSURE OF THE AIR. ON THE LEFT IS THE CYLINDRICAL DRUM WHICH ROTATES BY CLOCKWORK AND CARRIES A SHEET ON WHICH THE THREE PENS TRACE RECORDS OF THE DESIRED DATA. NEAR THE LOWER CENTER IS THE SYLPHON ELEMENT, AN EVACUATED BOX WHOSE EXPANSION WITH DECREASE IN ATMOSPHERIC PRESSURE PERMITS THE MEASUREMENT OF THE BAROMETRIC PRESSURE. NEAR THE RIGHT CENTER IS THE CURVED BIMETALLIC ELEMENT FOR MEASURING THE TEMPERATURE, AND BESIDE IT TO THE LEFT MAY BE SEEN SEVERAL STRANDS OF HUMAN HAIR WHOSE CHANGES IN LENGTH WITH MOISTURE IN THE AIR RECORD THE RELATIVE HUMIDITY.

samples of air thus obtained were later analyzed by Cavendish.

In 1803–4, a Belgian physicist, Robertson, made three ascents from Hamburg and St. Petersburg, the latter of which was made under the auspices of the Russian Academy with the object of determining the change in the rate of evaporation of fluids, change of magnetic force and magnetic inclination, and the increase of solar heat with increase in elevation. After some doubt was cast on



VIEW OF AIRPLANE

READY TO MAKE A METEOROLOGICAL SOUNDING TO A HEIGHT OF 17,000 FEET. THE AEROMETEOROGRAPH IS SEEN MOUNTED IN A FRAME ATTACHED TO ONE OF THE STRUTS BETWEEN THE WINGS.

Robertson's results, funds placed at the disposal of the French Academy of Sciences by the French Government were employed upon the proposal of Laplace to finance further balloon ascents. Two ascents were thus made from Paris, one on August 24, 1804, by Biot and Gay-Lussac to a height of 13,000 feet, and the other on September 16, 1804, by Gay-Lussac alone to a height of 23,000 feet. Samples of air were brought down, and later analysis showed the same concentration of gases as observed at the surface, except for water vapor, which was less. The variation of magnetic force with height was also studied.

Scientific ballooning seems to have largely languished for a number of years following this; however, we may take notice of the two ascents made by the Astronomer E. S. Rush with the famous aeronaut Green in September, 1838, and September, 1839, the latter of which reached an altitude of about 25,900 feet. In 1850 there was a revival of interest when J. A. Bixio and J. A. Barral made two ascents.

In 1852, Mr. John Welsh, of Kew Observatory, made a series of four ascents under the auspices of the British Association for the Advancement of Science. The maximum altitude he reached was 22,930 feet. Samples of air were collected, the changes of temperature and humidity observed and the light from clouds examined for polarization. Welsh was the first to inclose his wet- and dry-bulb thermometers (psychrometer) in a polished metal tube through which air was forced by bellows, in order to remove the vitiating effect of the sun, car and observers, on exposed thermometers, and his careful work and discussion of

results were models to be sought after in later years.

In 1858 the British Association again took up the project of scientific ballooning. Various difficulties prevented progress until the year 1862, when James Glaisher of Kew Observatory began his famous series of 28 ascents, which extended to the year 1866. The objects of the observations made concerned primarily the condition of the air in regard to temperature and humidity, and secondarily: (1) Comparison of various instruments for measuring humidity; (2) comparisons of the readings of an aneroid with a mercurial barometer; (3) examination of the electrical condition of the air at different heights; (4) determination of ozone by means of "ozone papers"; (5) determination of variation with height of the horizontal intensity of the earth's magnetism; (6) comparison of the solar spectrum at various heights and times of day; (7) collection of air at different elevations; (8) observation of height, kind, density and thickness of clouds; (9) determination of rate and direction of different currents; (10) observations on sound; (11) observations of solar radiation at different heights; (12) determination of the actinic effects of the sun at different elevations by means of Herschel's actinometer; (13) observation of atmospherical phenomena in general. Glaisher concluded that the thermometers, whether or not ventilated in a polished tube, as Welsh had done, gave the same results. This was later proved to be due to the fact that the instruments were carried either in the car or just beside it, and hence that the temperature and humidity readings were somewhat spurious.

However, valuable results were secured, and one can not help but admire the fortitude with which this investigator and his aeronaut Coxwell bore the discomforts of cold and "altitude sickness" brought about by the high ascents. On the ascent made from Wolverhampton, on September 5, 1862, Coxwell had mounted the ring above the car to disentangle the valve-line while at an altitude of 29,000 feet (barometer 9.75 inches) and the balloon was still ascending. Glaisher in the meanwhile observed that he could not see the hands of the watch nor mercury in the thermometer. Laying his arm on the table he found himself powerless to move it, and then his other arm became similarly affected. His head fell over on his left shoulder and soon he found himself unable to move his legs, back and neck. He fell into a state of insensibility and was finally aroused after several minutes by Coxwell, who in climbing the ring had frozen his hands, and feeling himself becoming senseless and noting Glaisher's condition, was forced to seize the valve cord with his teeth and dip his head two or three times in order to cause the balloon to descend. The maximum altitude reached was later estimated by Professor Assmann of Berlin to be about 27,500 feet. No inconvenience followed Glaisher's insensibility.

A series of balloon ascents in France by C. Flammarion, W. de Fonvielle and G. Tissandier, respectively, at various times during the period 1867–1875 did not end so happily, for on the ascent made from Paris on April 15, 1875, by Tissandier, H. T. Sivel and J. E. Crocé-Spinelli to a height of about 28,000 feet, the latter two were asphyxiated due to the rarefied air, while Tissandier was unconscious about two hours and the balloon fell to earth four and a half hours after the ascent. This unfortunate occurrence caused the cessation of high-altitude scientific ballooning for some years.

It is an interesting commentary on the history of scientific ballooning that a war was the indirect cause of its ultimate revival. It is not often remembered that during the Franco-Prussian war of

1870–71, when Paris was besieged by the Germans and it was impossible to communicate with the outside world from that city by ordinary means, the French Government established two factories for the manufacture of balloons, which were principally used to carry despatches to the unbeleaguered territory of the country. Thus a total of 61 balloons left Paris during the period from September 23, 1870, to January 28, 1871, carrying about 153 people and a total of about 2,500,000 letters, also with a number of carrier pigeons to provide the means for return communications. This led to a distinct recognition of the value of ballooning for military purposes and hence the formation of a number of balloon detachments by the German army. So that in 1879, when Dr. Wilhelm Angerstein attempted to start an organization for the development of aeronautics, he was enabled to enlist the interest of a number of parties, particularly officers of the German army, and in 1881, there was formed the German Society for the Promotion of Aerial Navigation at Berlin. This attracted few meteorologists at first, but in 1887 there was a considerable influx of them into this organization. In June, 1888, the famous meteorologist Von Bezold proposed that the society make ascents of a scientific nature. This was acted on forthwith, the first flight being made on June 23, of that year, using a military balloon.

At this period the meteorologist Dr. Richard Assmann, who was greatly concerned with the problem of obtaining reliable temperature readings in the free air, developed his "aspiration psychrometer" which consisted of two thermometers, one wet and the other dry, enclosed in highly polished tubes side by side, with provision by means of a centrifugal suction fan at the top of the tubes for drawing a rapid stream of air past the thermometers. This was found to give accurate readings little influenced by exposure to the sun, thus permitting correction of the faulty results obtained by Glaisher.

Little by little the society was able to expand its work of scientific ballooning, first by assistance from military authorities and private individuals, then by the Royal Academy of Sciences at Berlin and finally by three separate grants of money by the German Emperor. Special balloons were built for this work, and by December, 1894, about 43 scientific manned-balloon ascents had been made.

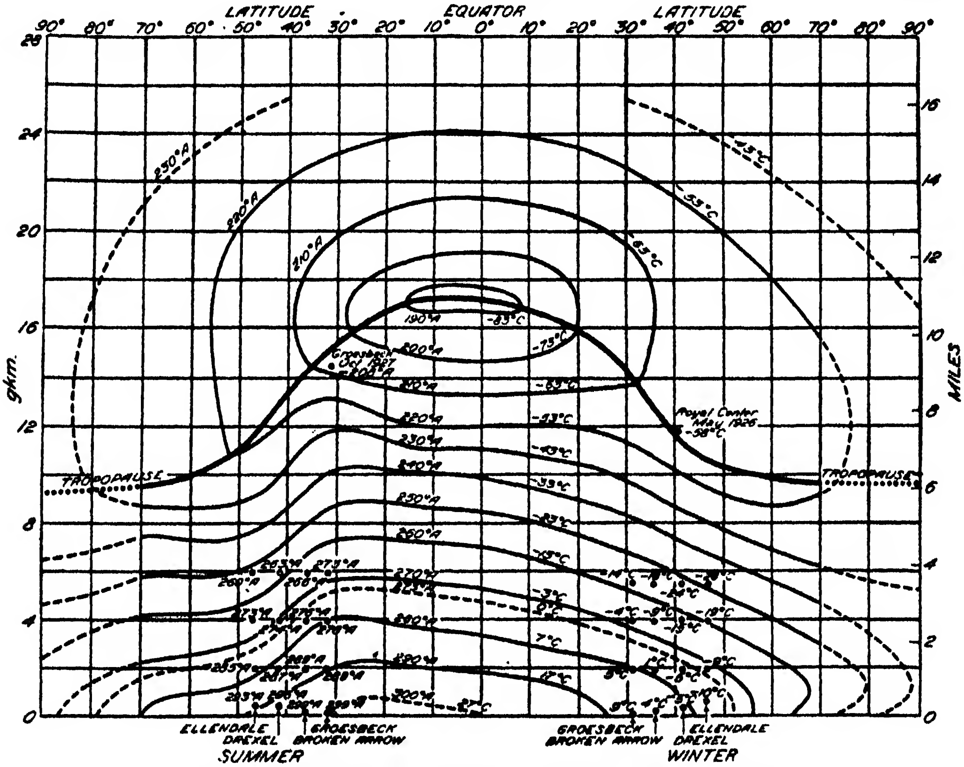
In the meanwhile, progress had been made along another line in France, for in 1879 Brissonet and in 1881 Jobert and Silbermann suggested that one might release small free balloons with tags attached, requesting the finder to communicate with the releaser and thus determine the direction of the upper winds. Consideration was also given to the possibility of attaching light self-recording instruments to the balloons to determine the temperature of the upper air.

Since such instruments were not available, the idea was not carried out, just as this limitation had blocked progress when the same idea had been presented in a prize problem given as long ago as 1809 by the Royal Society in Copenhagen. In 1891, Gustave Hermite and Georges Besançon began to work in this direction, and in March, 1892, they sent up small balloons, some of which carried a simple device for dropping cards periodically to permit the path of the balloon to be followed. Later that year they made small balloons of oiled paper or goldbeater's skin and constructed a primitive instrument consisting of an aneroid barometer to record the lowest pressure attained in the ascent and two thermometers, one to record the minimum and the other the maximum temperatures encountered. The first time this instrument was used the balloon was beaten down by rain;

however, between October 4, 1892, and December 10, 1892, they succeeded in launching 14 balloons with simple self-recording instruments, all but one of which were subsequently found. The maximum altitude attained in these experiments was about 9,000 m. (29,527 ft.).

balloon of 113 cubic meters (3,990 cu. ft.) capacity, containing illuminating gas, and released on March 21, 1893.

It attained the great height of about 15,000 meters (49,212 ft.) and recorded a minimum temperature of about –51° C. (–60° F.), thus establishing the first important record for meteorological



VERTICAL SECTION THROUGH THE ATMOSPHERE

SHOWING AVERAGE TEMPERATURE CONDITIONS AT VARIOUS LATITUDES IN SUMMER AND WINTER. THE THIN CURVED LINES, ISOTHERMS, PASS THROUGH POINTS OF EQUAL TEMPERATURE. THE HEAVY CURVED LINE, LABELED TROPOPAUSE, REPRESENTS THE BOUNDARY BETWEEN THE TROPOSPHERE AND STRATOSPHERE. THE FIGURES ASSOCIATED WITH THE SMALL CIRCLES REPRESENT AVERAGE TEMPERATURES AT FOUR STATIONS IN THE UNITED STATES: ELLENDALE, N. DAK., DREXEL, NEBR., BROKEN ARROW, OKLA., AND GROESBECK, TEX. (DIAGRAM ADAPTED FROM K. R. RAMANATHAN—SEE *Nature* (LONDON), JUNE 1, 1929.)

Proceeding further, Hermite and Besançon had constructed for them by the firm of Richard Frères in Paris an instrument weighing only 1.2 kg. (2.65 lbs.) for recording the barometric pressure and the temperature on a drum run by clockwork. This was attached to a sounding balloons (ballon-sondes), as these balloons were called.

Experiments with sounding balloons were quickly taken up in 1894 by workers in Germany, where the following year, on April 27, a balloon reached a maximum height of about 21,800 meters

(71,520 ft.). The instrument used in this country was that constructed by Dr. Assmann wherein the record was fixed on sensitized photographic paper and artificial ventilation was provided for the thermometers by means of a suction fan driven by a falling weight attached to a long wire.

The same idea was also carried out by Léon Teisserenc de Bort in France. However, the need for artificial ventilation was found to be unnecessary upon the development, separately by the last-named investigator and by the German meteorologist Dr. Hugo Hergesell, of a very light and sensitive bimetallic temperature element.

The use of sounding balloons spread rapidly to other countries after this, for at a meeting of directors of meteorological services held in Paris, September, 1895, there was organized the International Commission for the Exploration of the Upper Air, which took upon itself the task of securing international cooperation in this important field.

After consultations, November 14, 1896, was selected as the first day on which simultaneous ascents were to be made from a number of countries in Europe. On this day two balloons rose from Berlin and St. Petersburg, respectively, and one each from Munich, Strassburg, Paris and Warsaw, eight in all, four of which were sounding balloons and the remainder manned balloons.

Elaborately equipped observatories for upper-air investigations were established in the latter part of the period which we have been discussing, particularly the one at Lindenberg, Germany, and Trappes (1898) near Paris, France. At these places extensive programs of upper-air investigation were begun, and at Trappes, under the direction of Teisserenc de Bort, 258 sounding balloons were released between 1898 and 1902.

In the spring and summer of 1905, Dr. Hergesell made sounding-balloon ascents on the Mediterranean and Atlantic from the yacht *Princess Alice,* belonging to the Prince of Monaco. In 1906 and 1907 Teisserenc de Bort and A. Lawrence Rotch, of Blue Hill Observatory (Massachusetts), collaborated in making similar ascents, a maximum height of 17,800 meters (58,400 ft.) being reached.

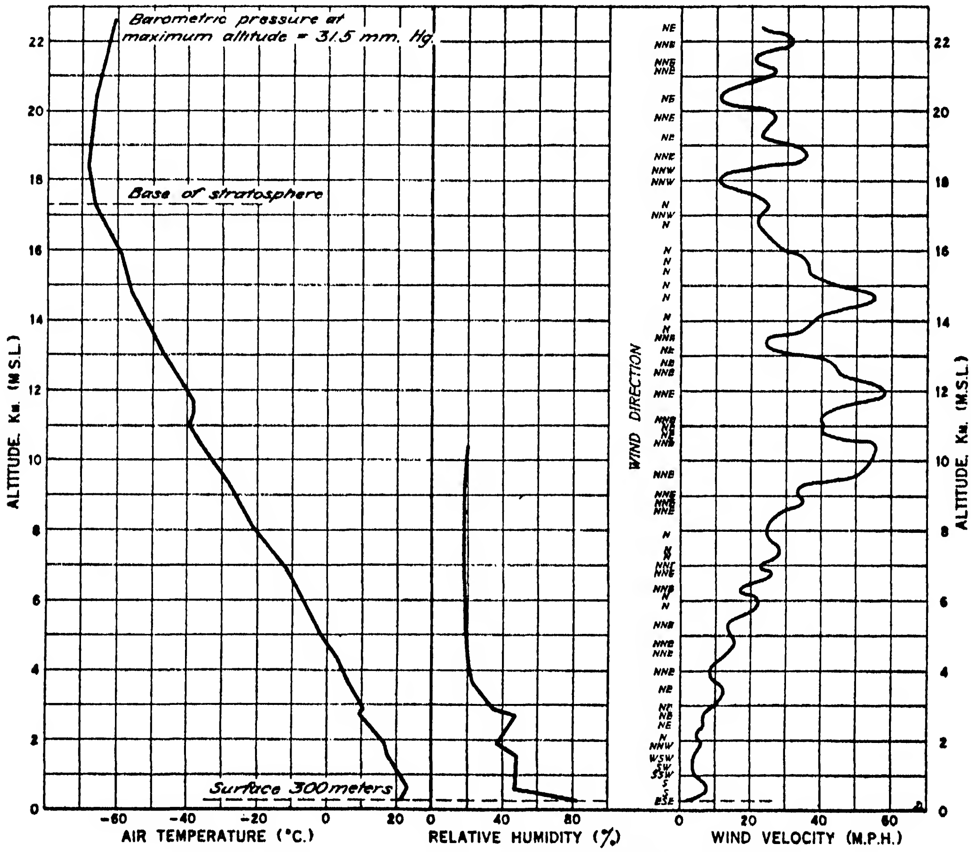
For this work the following scheme was evolved: the instrument is carried up by two balloons having dimensions such that one balloon is insufficient to give the necessary ascensional force. On the ascent one balloon bursts, allowing the other to descend slowly to the sea. The instrument is supported above the water and thus prevented from sinking by being attached between a float and the remaining balloon.

With the development which we have outlined, the inherent advantages of sounding balloons for purposes of exploring to great heights in the atmosphere became clearly evident; and open-basket manned-balloon flights for scientific purposes were gradually abandoned after having reached their culmination on July 31, 1901, in the ascent made by Drs. A. Berson and R. Süring of Germany to a height of about 10,800 meters (35,430 ft.), where they became unconscious despite the use of oxygen. It was thus with the aid of the sounding balloon that the stratosphere was discovered, first attention to it being called in 1899 by Teisserenc de Bort in a paper presented to the Physical Society of France, and again in a paper published by the same investigator in March, 1902, and independently in a paper by Dr. Assmann presented before the Prussian Academy of Sciences in Berlin on May 1, 1902.

Since 1899 much has been learned regarding the structure of the upper atmosphere, especially as a result of the free-air observations sponsored largely

by the International Commission for the Exploration of the Upper Atmosphere and by various meteorological services. Through the work of this commission international cooperation has so grown in scope that practically every civilized country on the globe now participates each year in an intensive program of upper-air soundings, covering some definite prescribed period such as a month. The comparative study of the data so obtained has led to a new branch of meteorology, *viz.*, the climatology of the upper atmosphere, some of the principal results of which we shall next outline.

The first illustration shows the launching of a sounding balloon at Omaha, Nebraska, Oct. 27, 1932. The balloon is made of thin rubber, with a total weight of 2 lbs.; its diameter is about 5 feet when released and its ascensional rate is 825 feet per minute. The parachute seen just beneath the balloon slowly carries the meteorograph down to earth after the balloon bursts. The maximum height ever reached by a sounding balloon is 35.9 km. (22.3 mi.).



RESULTS OF SOUNDING BALLOON OBSERVATION

MADE AT OMAHA, NEBR., 7:12–8:46 A. M., JULY 27, 1933. THE WIND VELOCITY AND DIRECTION WERE OBTAINED BY DETERMINING THE HORIZONTAL TRAJECTORY OF THE BALLOON AFTER OBSERVING IT THROUGH A THEODOLITE, AN INSTRUMENT LIKE A SURVEYOR'S TRANSIT, WHICH IS A TELESCOPE WITH HORIZONTAL AND VERTICAL CIRCLES FOR MEASURING ANGLES.

STRUCTURE OF THE ATMOSPHERE

If a celestial observer were to enter

the earth's atmosphere, he would find it subdivided into relatively thin shells. The lowest shell, which we call the *troposphere, he would find to be rich in water vapor and characterized by the* presence of numerous ascending and descending currents, which give rise to the formation and dissipation of clouds. Due to the heating of the earth by the sun, the remarkable power of water vapor to absorb radiant heat and the thermal effects of condensation, he would find the kilometer layer next to the ground the warmest, while above that he would note that the temperature fell with height at the average rate of about 0.6° C. per 100 meters (0.33° F. per 100 ft.) over a layer about 4 km. (13,120 ft.) thick, and still further above, that the temperature fell at the average rate of about 0.8–0.9° C. per 100 meters (0.44–0.49° F. per 100 ft.) up to a height in middle latitudes of about 11 km. (36,090 ft.), which is nearly the upper limit of the typical forms of clouds.

At this level he would discover a sharp change, for the temperature, instead of falling with increasing altitude, would be observed to remain essentially constant for a layer up to at least 35 km. (114,800 ft.). This upper layer or shell, which we call the stratosphere, he would find to be poor in water vapor and characterized by the relative absence of ascending and descending currents and of clouds. Since in general there can be no considerable amount of vertical convection in this region, motion must be largely horizontal or stratified, hence the name "stratosphere."

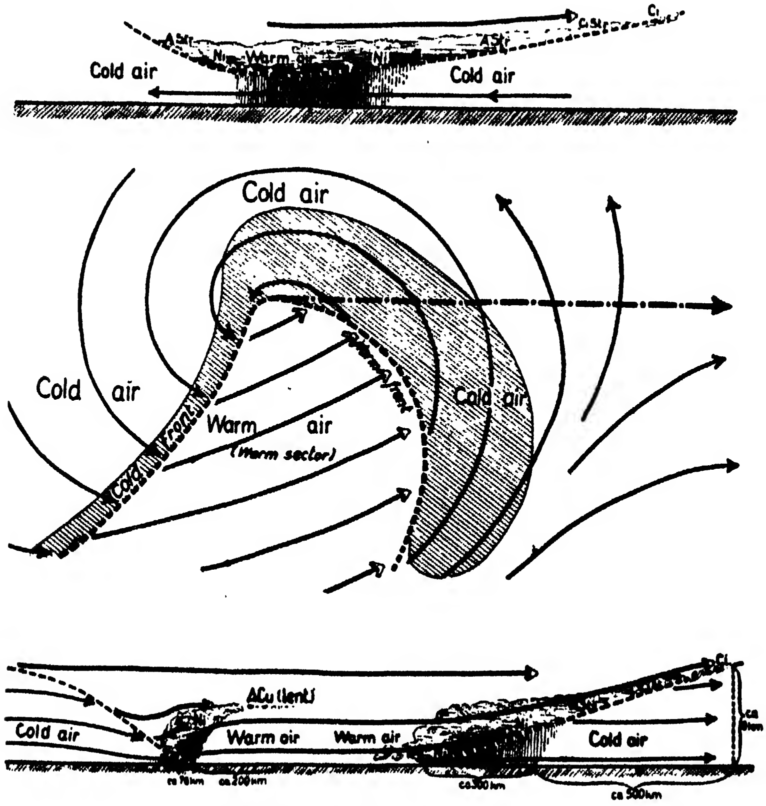
Our celestial observer would note that the lower shell or troposphere was not of uniform thickness over the earth, but that it had a hump over the equator to an extent of about 11 miles, while it tapered off toward the poles, where it reached only a height of about 5 miles. He would also make the perhaps astonishing discovery that the temperature at the top of the troposphere or base of the stratosphere was considerably colder over the equator than over the poles, *namely, about –85° C. (–121° F.) in contrast to about –45° C. (–49° F.). In fact, he would find that the lowest* temperature ever observed by man in the atmosphere was about –92° C. (–134° F.) in the stratosphere over Agra, India.

With regard to winds, our mythical visitor would find that they increase with height on the average until one reaches a level just below the base of the stratosphere, where the maximum occurs. Here, in temperate latitudes the winds will be found to prevail from a westerly direction with velocities of from 40 to 80 miles per hour. Over regions near the equator, on the contrary, the winds prevail from the east with velocities of about 25 miles per hour. Above the level in question the winds will have been observed to decrease in velocity within the stratosphere to values of about 15 to 25 miles per hour, while the directions will appear to have easterly components even over temperate regions.

If our guest from afar had appeared at the proper time some years ago, he would have seen carried aloft by sounding balloons ingenious devices for capturing samples of air at high altitudes and returning them to earth ready for analysis. The chemist assigned to this task would, in presenting his results to our visitant, explain that at altitudes of 14 km. (45,930 ft.) to which a particular device, for example, had ascended, the constituents of the air except for water vapor existed in essentially the same proportions as at sea level. If our visitant were to go to the laboratory of Teisserenc de Bort and ask him to explain how his device operated, the latter would demonstrate by placing the apparatus under a bell jar and evacuating

the space within. He would observe that when the pressure fell to a certain value, an aneroid barometer in the apparatus would cause an electrical contact, thus releasing a little weight which in falling would break the finely drawn-out point of an exhausted glass tube into which the air would rush. Upon further decreasing the pressure, the barometer would cause another electrical contact to be made and hence close a circuit containing an electrical battery and a wire of high resistance wound around the remaining portion of the drawn-out tube. The heat thus generated would melt the glass and seal the tube containing the sample of air.

If our visitant were to go further into the past and make an ascent to high elevations, in company with our balloonist Glaisher, he would have observed that the sky became bluer as he rose and finally became a deep Prussian blue when an elevation of 6 miles was reached. At this elevation no ordinary sounds would reach his ear.



IDEALIZED CYCLONE

ACCORDING TO BJERKNES OF NORWAY. MIDDLE VIEW REPRESENTS HORIZONTAL SECTION THROUGH THE CYCLONE NEAR THE SURFACE OF THE EARTH. ARROWS INDICATE MOTION OF AIR PARTICLES WITH RESPECT TO THE CYCLONE. LOWER VIEW REPRESENTS VERTICAL SECTION THROUGH THE CYCLONE. CROSS HATCHING REPRESENTS CLOUDS; VERTICAL HATCHING, PRECIPITATION. UPPER VIEW REPRESENTS VERTICAL SECTION THROUGH THE CYCLONE AFTER THE "COLD FRONT" HAS CAUGHT UP WITH THE "WARM FRONT" AND LIFTED THE WARM AIR UP, THUS CAUSING PRECIPITATION.

We shall now leave our visitor from afar and look briefly at some of the problems which still confront the meteorologist specializing in the study of the upper atmosphere.

Problems of the Upper Atmosphere

The first and foremost problem concerns the elucidation of the vertical and horizontal structure of the cyclones and anticyclones of the lower atmosphere which go to make up our daily weather. For this purpose in years gone by, meteorological services made use of box kites to elevate instruments, called meteorographs, which automatically recorded the barometric pressure, the temperature and the relative humidity of the air. While this method gave valuable results it had the limitations that kites could not be flown in light winds, elevations exceeding 3,500 meters (11,480 ft.) were not often secured, and much time was consumed in the actual flying of the kites. This method has therefore been superseded by that in which airplanes[1] carry the meteorograph rapidly to elevations of 5,000 meters (16,400 ft.) or over and return within 1½ hours. The results thus obtained are telegraphed to the various meteorological centers for use in daily forecast work.

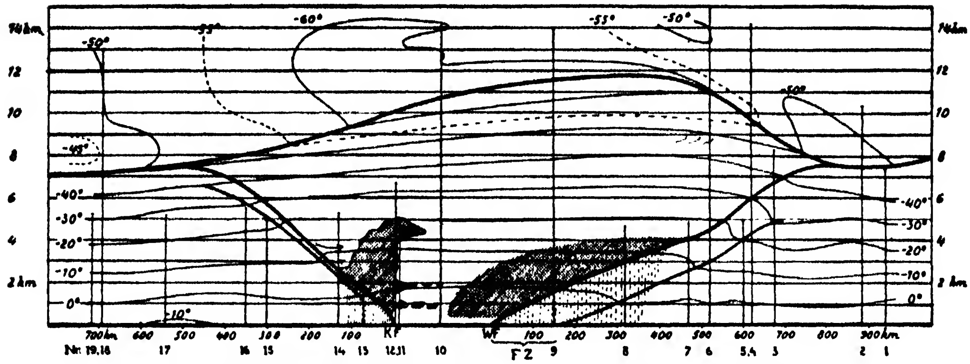
To obtain information for this purpose up to higher levels, other methods are necessary. With this problem before them, ingenious meteorologists and instrument makers of various countries, notably Moltchanoff of Russia, Duckert of Germany and others, have developed radio sounding-balloon meteorographs, weighing only about 3 pounds, which periodically send signals back to earth depicting the pressure and temperature conditions traversed during the ascent. These instruments were used during the International Polar Year from August, 1932, to August, 1933, at a number of stations in Polar regions.

The principle of radio direction finding has also been applied to balloons, using a base line of two receiving stations to determine the direction and velocity of the winds in the free air shown by the horizontal trajectory of the balloon as it is carried bodily along by the streams of air. If the two types of radio instruments mentioned can be combined into one instrument of compact and inexpensive design, a long step will have been made toward the desired goal.

Since finances play an important rôle in determining the extent of meteorological investigations, Jaumotte of Belgium has designed an inexpensive sounding balloon meteorograph weighing only 30 grams. No clock is used in this instrument, and the record is made on a piece of smoked mica the size of a postage stamp. This is projected optically on a screen to give high magnification and accuracy.

Of late years the plan has developed of releasing sounding balloons at intervals of 2 or 3 hours at a network of stations and thus reconstructing vertical cross-sections of the cyclones and anticyclones passing over the network. This has led to modification of many of the ideas held by meteorologists years ago. It has been of especial benefit in the study of weather from the view-point of the Norwegian or Polar Front Theory of the cyclone which holds that the cyclone develops as a result of the interaction of two streams of air, one cold and relatively dry of polar origin, and the other warm and relatively moist of tropical origin. Observations show that the cold air ordinarily moves as a mass with its boundary edges inclined to the ground at a small angle. These boundaries form discontinuities or sharp changes in temperature, and their intersections with

[1] Beginning on July 1, 1934, the United States will have a total of 24 airplane weather stations by cooperation between the Weather Bureau, Army and Navy.



VERTICAL SECTION THROUGH AN ACTUAL CYCLONE

ACCORDING TO BJERKNES AND PALMÉN (BEITRÄGE ZUR PHYSIK DER FREIEN ATMOSPHÄRE, BAND XXI, HEFT 1, LEIPZIG, 1933). THIN CURVED LINES REPRESENT ISOTHERMS. UPPER HEAVY LINE REPRESENTS THE TROPOPAUSE. HEAVY SLOPING LINE ON THE LEFT REPRESENTS THE UPPER BOUNDARY OF THE WEDGE OF COLD AIR FOLLOWING THE "COLD FRONT" (KF). HEAVY SLOPING LINE ON THE RIGHT REPRESENTS THE UPPER BOUNDARY OF THE WEDGE OF COLD AIR PRECEDING THE "WARM FRONT" (WF). VERTICAL LINES REPRESENT THE POSITIONS OF THE 19 SOUNDING BALLOON ASCENTS WITH RESPECT TO THE CYCLONE.

the ground are known either as "cold fronts" or "warm fronts." The raising (and hence cooling) of warm moist air up the slope of the cold air is believed to be a principal cause of precipitation.

A problem which has not yet been solved is the relation of the stratosphere to the cyclones and anticyclones of lower levels. The evidence now appears to point to horizontal mass movement, or advection north and south, of layers of air comprising not only the troposphere but also part of the stratosphere as primary factors in the development of the daily weather situations.

Further developments lie in the direction of exploring the higher reaches of the stratosphere, which to date has only been probed to a height of 35.9 km. (22.3 miles) in the sounding balloon ascent made at Hamburg, Germany, on September 8, 1930. Possibilities toward the attainment of this end may be found by applying heat artificially to the rubber envelopes of the balloons and to the hydrogen gas. However, it seems more probable that the solution may be found in the employment of rockets shot up to high altitudes. The projectiles fired by the Big Berthas which bombarded Paris from a distance of 75 miles reached altitudes of about 24 miles, so that these weapons of war may be turned to the purposes of peace and the advancement of science, if used to capture samples of air and perform other tasks of value.

The layer of ozone which spectroscopic observations indicate must exist in the layer between 35 and 60[2] km provides a field for further investigation. Its importance biologically can not be underestimated, since the solar rays which strike the atmosphere and are absorbed by the ozone would become lethal if the ozone were to disappear. This absorption of radiant energy by the ozone is believed to bring the temperature of this layer to values perhaps 50° C., or more, higher than those experienced on the earth during a summer day. The theoretical evidence for this is supported by the study of the velocity of sound in the

[2] These figures for the height of the ozone layer were believed to be true until quite recently. Authorities are now coming to the view that about half of all the ozone in the atmosphere exists below a height of 24 km., and that the maximum concentration occurs at a height of about 30 km. It is now also believed that nearly 10 per cent. of the ozone lies between sea level and a height of 8 km.

upper atmosphere following explosions at the surface. In this manner also is explained the zones of abnormal audibility noted so frequently during the world war.

From the drift of meteor trails in the upper atmosphere it has been possible to compute the direction and velocity of the winds at high levels. Many curious phenomena in this connection still require physical explanations. The heights at which meteors become visible are also employed as a means of estimating the density of the upper atmosphere and hence the pressure and temperature of the air at levels inaccessible to the sounding balloon. In this way temperatures of from 75° to 125° C. have been estimated at altitudes as high as 160 km.

Though the stratosphere is usually free from clouds, two kinds are occasionally observed there, and then only at night near the horizon toward the sun just before sunrise or just after sunset. Both of these types exist far above the height of the highest clouds found in the troposphere. The first type, the nacreous or mother-of-pearl cloud, is found at an altitude of about 25 km., and the second type, the noctilucent cloud, is found at an altitude of about 82 km. Both are generally visible only when the sun is below the horizon and illuminates their lower surface. The lower of these clouds are iridescent, as their name implies, and are believed to be formed of supercooled water droplets. The upper of these clouds are silvery or bluish-white in color, and may be formed of matter ejected from volcanoes or even possibly supercooled water droplets. The nature and origin of these clouds therefore require elucidation.

For a number of years meteorologists believed that in the upper atmosphere the heavier gases, such as nitrogen and oxygen, tended to sink by diffusion, leaving the lighter gases, such as helium, to exist in higher degree at great elevations. Evidence obtained from spectrophotographs of auroral displays and from other considerations now, however, points to the conclusion that nitrogen and oxygen, the latter possibly atomic in large measure, exist to great heights and that hydrogen and helium may be present only in minute quantities near the upper portion of the atmosphere. Here then lies a fertile field for further investigation: To determine the distribution of temperature, pressure and composition of the gases present, including water vapor and the elusive ozone whose variations with place and time are so mystifying.

At heights yet greater than those we have referred to, there still exist phenomena of interest to the meteorologist, *viz.*, the aurora at elevations from 100 to about 1,000 km., and the Kennelly-Heaviside ionized layer at elevations from about 80 to about 260 km. Both of these are known to have some relation to electrical and magnetic storms on earth, while the latter is known to cause the reflection of radio waves back to earth. Recently Martyn of Australia reported that when the average night-time ionization density in the E layer of the Heaviside layer showed an increase or decrease, the barometric pressure at the ground from 12 to 36 hours later showed a corresponding increase or decrease. If this is borne out, we have evidence that the changes of weather we observe at the surface of the earth are in some manner brought about by the same agencies as produce the changes in ionization at high elevations earlier, and/or possibly that conditions at 80 or more km. have a causal relation with the following weather at the surface. This opens vistas unseen years ago and indicates to the meteorologist that he may have to turn to the laboratory and avail himself of the new tools that science has developed in order to fully understand the sequences of the weather.

THE COSTS OF MEDICAL CARE

By RAY LYMAN WILBUR, M.D.
PRESIDENT OF STANFORD UNIVERSITY

SCIENCE has acted like a ferment throughout our whole civilization. The changes brought about by it have been so rapid that they are beyond the conception of most of us. We have completely rearranged our environment without any material change in ourselves. The social responses to the effects of science have been slow and the political ones even more so. Modern medicine built on science has been in the forefront in bringing about these changes.

We now find ourselves with a great mass of usable facts and with a splendid body of trained men and women ready to apply them for the benefit of humanity, but without an administrative or economic system which will give all members of our society an even or an adequate opportunity to profit by them. In every advance there are always those who struggle against it and those who must fight old enemies in order to be happy. The mould of the human thought machine changes very slowly. The pattern of emotions, prejudices and habits that make up a large part of human behavior is strangely resistant to the control of what we are pleased to call the intellectual processes.

There is no emotion in science. Its control depends upon the keenest and cleanest use of the mental faculties. It is natural that a considerable portion of those dealing with the sick should have their faces turned toward the past and that they should endeavor to use old formulae for new conditions. The automobile and the associated highways have changed all the time factors in medical practise. The automobile, the operating table, the microscope, the telephone, the test-tube, the Roentgen ray, the trained nurse, the interne, the mechano-therapist, are indispensable to the modern doctor. Each has its place and each costs money. We can not care for the intricate set-up of modern medicine by a bookkeeping system such as that of the past, which was built around the notes carried in the silk hat of the bewhiskered, lovable and friendly general practitioner.

Medicine has been built up step by step through persistent experimentation. The social applications of medicine require the same repeated and carefully controlled experiments. We should recognize that the scientific side of medicine is up-to-date and in full synchronization with the peaks of human achievement, while for the most part the social side and the economic side as developed now are often archaic and ineffective in operation.

The medical profession has been undergoing a dramatic transformation in the last twenty-five years. Just as civilization has been remoulding its environment, so medicine has been remoulded by those instrumentalities that are supplementary and accessory to the use of the trained mind and the trained hands of the physician.

In this country we have had the construction of great medical schools and laboratories. We have put hundreds of millions of dollars into hospitals. We have trained tens of thousands of nurses and technicians. The mere operation of the machinery of modern medical practise requires great administrative skill and enormous expenditures. The physician can no longer be independent of these great agencies. He can, though, command them and see that they are used for their highest purposes. But in order to do so he must take part in the business, social and economic reorganization that is required, so that these instrumentalities may function and so that he may do his share in seeing that all elements of the population receive a just

and fair proportion of medical attention. To bring this about, community coordination and some orderly plan that will provide the facilities and that will remunerate the physician and his associates must be worked out.

Out of the population in a given year only so many are sick. Of the people who are sick a considerable number are indigent and automatically fall into the taxpayer's pocket. The others belong to different economic groups. In America we have been on the way up all the time. We have not thought of a stratified society. We think of a constant rise of young men and young women from the bottom to the top. These young people want the very best medical care in the very beginning of their economic period of earning a living. We can picture readily the burden of sickness that strikes our nation in the course of any given year. We can prophesy just about what it will be in character as well as in extent; but no one can prophesy what the burden of sickness will be in so far as the individual is concerned. Only a comparatively few are sick, and yet those few must bear the heavy medical costs. The hospitals, the various laboratories, the dentists, the nurses, all come in for their share. The great mass of men and women want to pay their own way. They want to meet the costs of medical care. This is impossible at the present time unless we devise a method that will spread the payments over a much longer period of time than just the period of an illness. We must spread it, too, over large numbers of individuals rather than over a few. In other words, there must be periodic payments over a long period of time to provide for the concentrated costs of illness. Otherwise they can not be paid. This means that an insurance basis must be devised to give security to the physician and care to the sick.

The Committee on the Costs of Medical Care during its five-year study brought out many pertinent facts which can not be blinked. Most significant perhaps is the uneven blow which sickness strikes in the community. Among 4,560 families who kept records of their total medical charges during a year, we found a wide range of charges per family. There were 1,788 of these families whose total annual incomes for the year were under $2,000 per family. Forty per cent. of these low-income families incurred medical costs for the entire family of less than $25 for the year, 20 per cent. had charges from $25 to $50, 21 per cent. from $50 to $100, 14 per cent. $100 to $250, 4 per cent. $250 to $500, 1 per cent. $500 to $1,000 and 0.2 of 1 per cent. $1,000 to $2,500. Eighty-one per cent. of this group had bills of less than $100 for the year and, we may assume, could pay their medical charges without serious hardship, but the remaining 19 per cent. must impair their living standards, draw on savings or borrow money if they are to meet their expenses. The 81 per cent. paid only 36 per cent. of the total bill of the entire group, while the 19 per cent. were faced with 64 per cent. of the amount, making the average per family eight times as high in the latter group. Among the higher income groups, the situation is roughly similar. In any particular year most families have moderate medical expenses in view of their total incomes, while a few families, perhaps 20 per cent. of the total, are taxed beyond their means. Next year, fortunately, a somewhat different group of families will constitute the 20 per cent.

The essential fact is that medical charges fall with great unevenness on different families during any given year and on the same family during the course of several years.

No well-informed student of medical economics believes for a moment that the patient's difficulty in paying medical costs is primarily or basically due to excessive fees on the part of physicians and other practitioners. There are a few "gougers" in medicine, of course, just as there are in all walks of life; but any

impartial analysis of the incomes of physicians leads to the conclusion that in view of the time devoted to training and education and the responsibilities assumed, there is no general overpayment of practitioners. For instance, the 79 practising physicians in San Joaquin County, California, had a median net income in 1929 of $5,500; in Philadelphia 245 representative physicians reported net incomes for 1928 for which the median was $4,200; 137 Vermont practitioners reported net incomes for 1929 with a median of $3,400; and 30 physicians in Shelby County, Indiana, had a median income in 1928 of $3,100. Some unpublished data regarding physicians south of the Mason-Dixon line indicate that conditions in certain large areas of the South are such that large numbers of physicians in 1930 received net incomes of less than $1,000. On the average the general practitioners reporting have net incomes about half as large as the specialists. Dentists in twenty states reported median net incomes for 1929 of $4,000.

Most of these figures are for 1928 or 1929. In 1930 physicians' incomes fell off appreciably, and at present the situation is doubtless even worse. In fact, one of the most significant aspects of the practise of medicine in the United States is the financial precariousness and insecurity of the major practitioners concerned.

It is obvious that we can not assume that the payment problem arises primarily because physicians receive incomes that are too large. Its roots go deeper than that. It rests on two principal bases: First, the physiological nature of the human structure, and the resulting uncertainty, so far as the individual is concerned, of the time and the place and the nature of the illness or illnesses which will affect him; and second, the uneven distribution of wealth in the United States and the apparent inability of a considerable number of people to do more than meet their current expenses. We feel reasonably confident when we say with Hermann Biggs, "*Public* health is purchasable." Our experience has been that if we perform certain tasks faithfully and conscientiously our mortality and morbidity rates will fall. But to the *individual,* we must be much more guarded in our promises. We may assure him that he can avoid diphtheria and smallpox and probably typhoid fever and certain other diseases. We can point out the benefits of sane, wise living, of reasonable exercise, of adequate rest and of proper diet. We can suggest an annual physical examination. Yet, although the individual may faithfully follow our advice, we can not assure him that he will escape all expensive illness. For the *group* we can now predict with a fair degree of certainty the incidence, duration and severity of the illnesses which they will have; for the *individual* definite prophecy is impossible.

In the light of this uncertainty it is easy to discern the psychological barrier to saving money in anticipation of an uncertain attack of illness which, if it comes, will cost an unpredictable amount. Even if a family does save, it has no way of assuring itself that the saving will be adequate.

But the uncertainty and the resulting adverse psychology are not the only obstacles. We must also face the fact that we distribute the fruits of our economic harvest in such a way that numerically important sections of our people have little surplus after paying even minimal amounts for food, clothing and shelter. In 1926, according to a careful estimate, 32 per cent. of the families in New York received annual incomes of less than $2,000 per family and 48 per cent. received less than $2,500 per family. In a large majority of cases this income represents the earnings of more than one member of the family. Most of these people can pay something for medical service and, if fully employed, they are able to pay their medical expenses during times of normally good health. But

a serious illness involving hospitalization and special nursing as well as the services of one or more physicians quickly bankrupts them.

Paradoxically enough, the problem has been sharpened by the very advances in medicine on which we pride ourselves. As automobiles have improved in quality, they have been more widely sold, and as a result have decreased in cost. But the greatest danger an economist runs in probing the economics of medicine is that he will expect to apply the automobile techniques and criteria and will not realize the deep significance of the difference between a personal, professional service and an impersonal, manufacturing or commercial process. In medicine, as our methods of measurement, of observations and of treatment have grown in objectivity and precision, they have of necessity in many cases become more, rather than less, costly. The saddle-bag day of medicine has passed and the new era has brought us new problems. We can not disregard modern methods. Although we all realize that complicated laboratory equipment is no substitute for the careful, thorough attention of a skilled mind, we also realize that if we are to practise medicine scientifically, if we are to do our best for each patient, we must have available many expensive tools and must utilize many procedures that were unknown to our grandfathers. Good medicine to-day has to be more costly than the good medicine of even twenty-five years ago.

The provision of adequate scientific medical service to all the people, rich and poor, at costs which can be reasonably met by them in their respective stations in life, is of vital concern to every one here in this country, for in every city, town and village are people suffering from rheumatism, cancer, venereal disease, diabetes, tuberculosis and other ailments. Thousands of persons, even in "good times," try to get along without the medical service they need. Hundreds of thousands postpone seeing the physician or dentist or going to the hospital because they are afraid the charges will be too high. Even among the wealthy it is only a small percentage who obtain all the preventive care that they really need.

This lack of adequate medical service lays a burden of pain, suffering and inefficiency on this nation which, rich as it is, exceeds what we can afford. The question which faces the American people in the next ten years is not whether we can afford to provide ourselves with satisfactory medical service, but rather whether we can afford to provide less than adequate health care.

The Committee on the Costs of Medical Care agreed that a satisfactory medical service was one which would fully meet the following essentials: (1) Safeguards the quality of medical care and preserves the essential personal relation between patient and physician; (2) meets the true needs of substantially all the people.

It should provide service on financial terms which the people can and will meet without undue hardship either through individual or collective resources. No one who has examined the data which have been gathered by the committee can doubt that the cost of medical care often constitutes a serious obstacle to a proper distribution of medical service.

A satisfactory medical program also must utilize known preventive measures. The old saw about "an ounce of prevention" is vitally true in the medical field. If we are to keep the costs of medical care within reason, we must make our major economy through the prevention of disease.

Our problem requires that we make full use of existing medical facilities, which can best be done by organizing many of them into medical centers; that we retain in any program the confidence and support and leadership of the trained medical profession, without whom no satisfactory plan can be

brought into being; and that we provide some form of payment for medical services which will spread the load over both sick and well and over all elements in the population. I see no escape from the insurance principle if medical care is to be given to those who need it and the physician and hospital are to be paid.

What difference does it make to a physician whether he is paid directly from the checking account of the patient or from a collective fund to which the patient has contributed? The essential thing is that the physician and not a bureaucrat determines all medical phases of the care of any patient, and that the patient has a voice in the selection of his medical attendant.

When we come to the question that was faced by the committee as to whether these group payments are to take the form of voluntary or compulsory contributions, naturally we meet differences in view-point that can only be worked out in time. We felt in the committee that it was safer to start off with the voluntary method, for we feared that the compulsory method carried out too soon with vigor and enthusiasm of legislative bodies (which might have members who want to be reelected on a popular cause) might project us into a field from which we might later wish to retreat. But if, after a few years, we have been able to demonstrate that there is a willingness to meet this charge, and that only those who fail to meet it are reluctant or negligent or indigent, then we can see our way toward some plan that may have the compulsory feature in it. In other words, we can develop a plan of compulsory health insurance gradually, if that should prove to be the answer.

The costs, as brought out by the committee, are not staggering—$20 to $40 per person per year. Using our present facilities, it is not a great cost when we think of how much many pay now who have more than the ordinary amount of illness to face. If we organize our talent for producing medical services economically and efficiently, a task well within the scope of America's peculiar genius, if we give thought to our navigating problems and plan our course to take fullest advantage of the wind, the waves and the strength and speed of our ship, we shall undoubtedly find that the cost is not too great for our present society. For inadequate medical services, produced with all the wastes inherent in individualized practise, we now pay about $30 per capita annually. With organized, coordinated effort we should be able to provide ample medical services of good quality to *all* the people and with proper remuneration to the professional personnel for a cost of somewhere between $20 and $50 per capita per year.

Throughout the nation we have had many different schemes given a trial. There is a tremendous ferment working in our medical system. Both doctors and laymen are reaching out in various directions to find methods of leveling the cost of medical service and of providing a better quality of care than has previously been available. Where this evolution will take us, we know not. That it contains dangerous as well as hopeful possibilities is apparent. If the costs of medical care can be approached without prejudice and preconception, if we can get the doctor to go at this problem of the social reconstruction of medicine in the same way he would take up the treatment of an old disease by a new method we can offer to the American people the greatest opportunity for happiness that can come to them from any present source.

It seems that American ways of providing medical care for all on a basis that retains dignity and self-respect are available. By cooperation and weighed experimentation the best plans can be rapidly evolved on the basis of the facts presented by the Committee on the Costs of Medical Care.

ETHICS AND RELATIVITY

By Dr. E. A. KIRKPATRICK
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WRITING on "The New Burden of Behavior" in the October SCIENTIFIC MONTHLY, Dr. Patrick suggests that the time is ripe for the application of scientific methods to problems of behavior. The present writer has been studying the possibilities of so doing for the past ten years and believes that changes produced by science are decisively influencing ethical practises and beliefs and that scientific research will ultimately solve many ethical problems. Perhaps, as Dr. Patrick says, we need a genius like Einstein to tell us "not about space and gravity but how to behave in this new and perplexing world—and why." We have had many able philosophers who professed to do this, yet they have had little effect upon the behavior of the great mass of human beings. Rarely have the theorists themselves lived in accordance with the ideals set forth. Even those who realized the impossibility of living ideally surrounded by a naughty world, and who therefore constructed imaginary social utopias, have had little influence on sociological organizations and codes of conduct. Human beings go on their way almost as independent of moral theories as the stars are of physical theories of gravity.

I

Most of the real progress in astronomy has been made by careful students of facts rather than by physical theorists. It is the student of the relative movements of the planets who has made it possible to predict the exact location of any planet at any given date in the future. In ethics we need, not so much theories of how man ought to behave as studies of how he does behave, which will enable us to predict how he will act under given conditions.

Man's characteristic behavior can not be determined by studying the nature of individuals only, but by studying the behavior of man in relation to his environment, physical and social. Only a little observation is necessary to show that everywhere men living in groups engage in common practises approved by all, and that they frown upon and usually punish acts contrary to these accepted ways of behaving. In other words, they develop ethical or moral standards by which they determine what is right or good. These standards are never quite the same for any two groups of people, and they are all subject to change. This means that the standards are relative instead of absolute, as supposed by theoretical moralists. The science of astronomy is not vitiated by the acceptance of the theory of relativity in physics but is made to seem more reasonable thereby; and a similar result may follow the acceptance of the doctrine of relativity in morals. We must study the underlying forces manifested in human behavior and find out what general truths account for the gravitation of human behavior to definite forms approved, at least for the time, by nearly all, and practised by the majority.

II

Without attempting at present to describe the essential elements of human nature, we will give attention to man's responses to his environment. He is continually reacting: (1) to material things; (2) to the customary reactions of those around him to things; (3) to the customary reactions of the people

around him to each other; (4) to the special reactions of other people to him as an individual. We may study human beings in all parts of the globe and in all stages of history and discover general truths of how the behavior of each group is influenced by these four phases of the environment.

(1) There is sufficient similarity and permanency in the characteristics of objects and in the nature of all human beings to insure that the reactions of all persons to objects, when uninfluenced by customs or people, will be very similar. They will all react negatively to painful and dangerous things, and positively to those giving safety and comfort. However, their knowledge of how to avoid what may be dangerous and to secure what is satisfying differs greatly. Since knowledge gained by individual experience only is very limited, many reactions to things fail to give the safety and satisfactions desired.

(2) The second phase of the environment, the customs of the group in the use and avoidance of things, is based on the much wider experience and knowledge of the older members of the group and also of their ancestors. In reacting to these customs in a conforming way, one's reactions to things are relatively better in the sense of improving his chances of survival and comfort. These customs, however, are subject to change, especially after things have been studied by the more exact methods of experimental science. In our present civilization men are more and more directing their reactions to things in accordance with the results of scientific research, rather than according to their own observation or the customs of their elders. They are inclined positively toward what science shows to be healthful and satisfying, and negatively toward what science indicates is dangerous and unpleasant, and hence old standards of conduct are breaking down. In its very nature science is universal, and as its sway spreads it brings into use the same objects of nature and the same inventions and thus tends to make the reactions of all peoples to things more nearly alike in fundamentals, although special objects and situations induce people to live somewhat differently in one locality than they do in other places. Economic, medical and social reactions, so far as they are directed by scientific knowledge, tend to become nearly the same the world over. Injurious economic practises, the use of inefficient medical methods and ignoring social welfare become matters of right and wrong in the light of science. To fail to provide economic security by insurance or otherwise, to fail to disinfect surgical instruments, to keep large numbers of insane persons in strait-jackets or to fail to educate children—all these things are now universally regarded as wrong. Thousands of ethical codes are developing as the result of scientific findings and are securing world-wide adoption.

(3) The third type of reaction, which is to the customs governing the relationship of individuals and social classes to each other, is less quickly, directly and evidently modified by mechanical inventions and the growth of scientific knowledge, and yet it is just as surely being changed.

Among nearly all peoples in past history, customs have decreed that members of families behave toward each other in certain ways, that behavior towards members of one's own community, tribe or nation be different from that toward members of other groups and that certain individuals—kings, priests or persons of different social status—shall practise and require special types of behavior regardless of the individual characteristics of the king, priest, aristocrat, or what not. These customs were associated with beliefs that such persons really differed from ordi-

nary persons. The effects of increased knowledge of physiology and psychology is to reveal all persons as fundamentally the same, and this leads to customs of behaving to a greater and greater extent in essentially the same way toward persons of all classes, and to expect the same behavior on their part. These ideals are gradually becoming established customs to which the new generation is conforming; hence the decay of reverence.

In most civilized countries it is now agreed that all persons are equal in the eyes of the law, and public opinion approves of the same general type of behavior toward people of all classes. International law also recognizes no social difference when one nation demands of another protection for its subjects. With further development of scientific knowledge and of facilities for travel and communication, there wil' be world-wide approval of the same types of behavior in most details towards all men. When these tendencies have developed further, conflicts between classes and nations, arising from the belief of each that they should have special favors in the way of behavior toward others and of others toward them, will cease. The same regulations will then apply to all classes and nations, and the majority of nations and the mass of people in each nation will unite in supporting such regulations. There will then be resistance only by a minority who are striving for special treatment favorable to themselves.

(4) The fourth form of reaction to phases of the environment, that of reacting to individuals, is still less directly and evidently modified and controlled by increased scientific knowledge, and yet it is subject to the same influence. Human beings are not all alike: there are fundamental differences between (a) the sexes, (b) children and adults, and (c) individual adults who vary in physical strength, intellectual ability and in emotional and volitional characteristics. This makes it inevitable that the interactions of individuals as individuals to each other shall be influenced by these differences. Repeated reactions of the same individuals to each other render the behavior of each toward the other as of a still more special character.

(a) The universalizing of knowledge, however, may have very marked effects upon the behavior of these naturally different types of persons to other types. This is most evident in the case of the behavior of the members of the two sexes toward each other. Old ideas as to the differences between men and women and of the correct behavior toward each sex have been greatly changed in the direction of recognizing their fundamental physical and mental similarity and to corresponding changes in customs of behavior more nearly the same toward all. When the sciences of physiology, psychology and sociology have been further perfected and customs correspondingly modified, the approved hetero-sex behavior will still differ in certain details from the approved intersex behavior, while most other behavior reactions of the two sexes will be on nearly an equal plane, as they now are economically and politically in the United States. The recent changes in women's behavior and in men's reactions to these changes in all civilized countries and especially in Russia, while not due wholly to increased knowledge of the near equality of men and women, will inevitably be perpetuated in a scientific world. In other words, science will determine the types of behavior which will be generally approved and practised in dealing with the same and with the opposite sex, although individual men and women will behave in special ways toward each other.

(b) The differences between infants and adults and, if family life continues, the necessarily intimate interaction between parents and children will make

inevitable certain differences between behavior of adults and parents toward children and of children toward parents and other adults. These differences are especially marked during the period of helpless infancy, but as fast as the child gains power of self-direction, the reactions of adults to children and of children to adults need to be varied only on account of differences in strength and knowledge. The right of the parent to demand obedience and the duty of the child to render it is now questioned in the light of scientific truths of mental hygiene for both adult and child.

(c) The relationship between strong and weak individuals of whatever age, and of intelligent and ignorant, will always be of a somewhat special character. They can not compete on an equal basis, and the tendency is for the stronger and more intelligent person to dominate the weaker and more ignorant, either to the advantage of the strong, or because of love, to act in the interest of the helpless and innocent. Scientific studies of personality and of mental hygiene, however, show that conflicts are decreased when persons of differing ability cooperate in gaining common ends instead of one dictating the ends and directing the activities of the other. Such cooperation is greatly increased in an age of specialization and of scientific domination. In polite society, in schools, in industrial establishments and in institutions of nearly all sorts (armies partly excepted), authority is giving place to cooperative and reciprocal behavior in reaching common and special ends.

In the early days of the factory systems authority grew, but is now declining, and employers and laborers, when they can not completely cooperate, are more frequently agreeing upon behavior involving reciprocal advantages. Scientific management is now concerned not only with elimination of waste of materials and movements, but with methods of dealing with employees and with the formulation of codes for the conduct of industrial and business activities. Fact-finding commissions are numerous, and legislators, courts and leaders of public opinion are more and more rendering judgments of ethical behavior in the light of scientific findings rather than on the basis of old customs.

III

In order to see more clearly the part that science may play in determining behavior we must take note not merely of the effects of environment upon the reactions of men, but must study human nature and note some of the laws governing the adjustive reactions of men to other men. It is natural for all men to adjust their reactions not only to their physical environment but also to their companions in such ways as to secure their own continued existence and satisfaction. This means that they inevitably modify their own behavior by what they know is likely to be the response to their acts from their fellows. This tendency is especially evident when one is surrounded by equals who can make their approval or irritation effective. In general, an aggressive act excites aggression in others, while a kindly act induces helpful ones. The aggressive acts of two persons or groups often increase in intensity with each response of the other, but after repeated conflicts each fighter learns to avoid going too far because of what the other is likely to do. As a consequence, when the same parties are in frequent conflict some sort of rules of fighting usually develop which prevent either party from trying to exterminate the other without regard for age or sex or the means used. Fighting with fists, with weapons in duels and with germs or gas in war have generally developed rules of civilized and uncivilized fighting, violations of which have been severely condemned. In competitive busi-

ness and in games, rules of behavior are always adopted and ultimately approved as right if they bring greater satisfaction to all concerned.

Putting the matter in brief form, whenever men react to each other frequently in similar situations, they sooner or later make adjustments, each in the light of how the other responds, until ways of reacting are found which in view of the action of the other party will be least unsatisfactory. Each is willing to do or to refrain from doing certain things if the other acts in a similar way and both gain thereby, *e.g.*, turn to the right. Customs of this kind cause each to expect the usual or right act from the other, and each assumes responsibility for obeying the same rule. Among all groups such codes of right develop. How quickly they develop and how effective and satisfactory they prove depends in part upon the frequency with which the same situations are met, and in part upon the disposition, intelligence and enlightenment of the reacting parties. Knowledge gained in part by experience and in part revealed by the science of social psychology will induce intelligent individuals to act on the general truth that all behavior must be adjusted, not merely to the objective situation, but in relation to the known or probable behavior of others. Codes of behavior that will more quickly bring about satisfactory conduct on the part of persons associating with each other may be formulated in the light of such knowledge and modified in the light of experience so as to secure general endorsement and conformity, *e.g.*, obey signal lights.

We see, then, that man's nature as a creature seeking to preserve his own life and health develops modes of action when he is associated with others which inevitably lead to behavior generally recognized as right. Such rules are more favorable to the survival and satisfaction of all members of the group than acting without regard to what others wish and are likely to do. In other words, acts approved by all are more satisfactory than acts for self-advantage which are not adjusted to the desires of others.

There is another side to human nature which must not be ignored in studying problems of behavior. Men's actions are not unfrequently determined more by their emotional attitude toward another person involved in the situation than by the possibilities of the situation itself. The value of a disputed piece of property or the success of cooperative efforts are often almost ignored in the effort to injure an enemy or help a friend. This purely personal factor influencing behavior to a greater or less extent involves actions which may be called "good" or "bad," without in all cases being judged by the group as right or wrong. The individual behavior of persons intimately associated renders the development of codes of conduct, based on scientific findings as to what is of general advantage to the group, very difficult. The politician still believes in being "good" to his friends, the civil service reformer in giving the most efficient man the job.

In general, the development and the observance of codes of right are hastened and perfected by all means that add to the general good will and are slowed or prevented by those producing ill will toward individuals and sometimes by developing excessive good will toward other individuals, regardless of how others of the group are affected thereby. Additional development of scientific knowledge of personality will doubtless result in more persons having the attitude of good will or loyalty to the group, and of more good will and less ill will toward individuals.

There is one way in which the effects of good will or ill will on the development and practise of moral codes are

now being continually minimized. Ill will and good will have the greatest influence on conduct when people are in face-to-face contacts with each other, and when each is acting according to his own nature rather than following a prescribed course of action. In all large organizations officers and employees when on duty are acting toward each other and toward clients in accordance with policies and regulations prescribed and practised by the leaders and managers and by the traditions of the institution. The customs of polite society also prevent many manifestations of personal attitudes which would otherwise call forth good will or resentment on the part of associates.

The results of inventions and discoveries of science have tremendously increased the number of non-face-to-face associations of people with each other. Buyers and sellers often never meet personally, while producers, transporters and consumers of goods and users of works of art and literature are rarely in personal contact with each other, and the codes of right behavior in their relations to each other are more influential than personal ill will or good will. Smiles and pleasant words contribute somewhat to the good will felt toward an organization; hence these are encouraged by business firms, railways, telephone companies and by educational and social institutions in dealing with individuals. Yet the security dealer or the head of any institution who seems oversolicitous regarding the personal welfare of a client is regarded with suspicion.

The importance of personal ill will and good will in the ethics of modern life has diminished to such an extent that we may raise the question whether in the social field a science of ethics of an almost completely objective character may not be developed, leaving only the field of reactions of individuals to individuals still not completely dominated by scientific findings. This problem of objectivity of ethical science may be discussed at another time.

IV

This article may be closed with a further brief reference to relativity. Many who have discussed ethical problems have seemed to assume that at least a *concept* of absolute right and of goodness is attainable. Scientific concepts, however, are all relative, and the author believes that no progress in the solution of ethical problems is possible until the idea of an absolute right is abandoned and the facts of man's reactions to things, to customs of his group and to individuals are investigated. The nature of an act varies with its setting and in relation to near and remote objective and subjective consequences. It would be useless to attempt to develop an absolute science of bridge building or of agriculture, and it is just as useless to strive for an absolute ethics. Notwithstanding the influence of custom on constructive practises, agricultural operations and ethical judgments, scientific knowledge will ultimately determine what practises will generally be approved.

Progress in developing efficiently right conduct in accordance with scientific knowledge is slower in ethical than in material sciences, but no less inevitable. Scientific knowledge is in its nature universal, and when it has spread to all nations it will make the essentials of ethical behavior the same the world over.

In studying ethical practises it is not necessary to decide what one thing is of the highest ethical value. All values are reflected in individual conduct, and since there must be adjustments of each individual's conduct to that of all other people affected by it, the codes of conduct finally developed and approved represent the resultant of the attempts

of all to gain what they regard as of most value. The values obtained by right conduct are the sum total of all known human values that are at the time practically obtainable by all. Other values dependent upon individual tastes, esthetic appreciations and personal effort may be attainable, but such values are not, properly speaking, ethical values because no uniform modes of acting are involved. In other words, there are many individual satisfactions not subject to general ethical valuation. Ethical conduct of individuals and the highest happiness of individuals are not identical.

Right is always relative to the approved practises of the persons most concerned and has varied extremely in different groups at different stages of human history. When all the world has come under the dominating influence of science the group differences will decrease, and the personalities of reacting individuals will be regarded as of less ethical significance. There is no reason to expect that right will ever reach a condition of unchangeability. Some peoples and some individuals will be relatively nearer to scientific right practises than others, and each will be influencing the codes and practises of the others. Science will also be advancing and new inventions and social organizations will always demand readjustment of ethical codes so as to make them relatively better. It is vain to hope that they will ever become such as can be called absolutely and eternally right and good, although some codes have worked well with minor variations in all groups of men in all ages, and hence may be regarded as more nearly approximating the ideal of the absolute, universal and eternal right which has inspired the thinking of moralists in all stages of the world's history.

The mills of human interaction grind slowly, but science is accelerating the adjustment of social organization and the emergence of finer working codes of behavior.

TO THE FUTURE BIOGRAPHERS OF JOHN QUINCY ADAMS

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THE recent biography of John Quincy Adams by Champ Clark[1] once again raises the question whether a biographer is at liberty to suppress or gloss over at will any of the leading activities or interests of his subject. Except for a brief chapter on the Smithsonian Institution, this biography has no word, good or bad, for the work of Adams in the promotion of science; and that chapter, indeed, does very little to retrieve the failure. The life by John T. Morse in the "American Statesmen Series" is similarly defective, and the early biography by William H. Seward (Auburn, New York, 1849) entirely so. Only the Memoir (Boston, 1858) by the historian and one-time president of Harvard University, Josiah Quincy, gives a fair indication of the passion which Adams felt and the labor which he endured for the "increase and diffusion of knowledge among men."

The formal education of John Quincy Adams, secured in the intervals of travel and amidst the distractions of diplomacy, was almost entirely a literary one. He read the usual Latin and several of the Greek authors in their own languages. He cultivated a close acquaintance with the English and French poets, and he spoke the language of the latter fluently and accurately. "In truth," his father wrote, "there are few who take their degrees at college, who have so much knowledge." This was a claim as moderate as it was accurate in its emphasis; it was, in spite of his paraphrasing and poetizing, for his knowledge rather than his literary taste that John Quincy Adams was to become distinguished. In the same famous letter to Dr. Waterhouse, John Adams noted that in the course of the preceding year he and his son had spent their evenings upon Euclid, "instead of playing cards like the fashionable world." At Harvard, where the son now spent fifteen months and whence he graduated with honors in mathematics, the course which aroused his greatest curiosity and enthusiasm was one on natural philosophy. And the exact sciences, especially astronomy, were to be the objects of his keen interest throughout a life devoted to its last day to public affairs.

The eminence of John Quincy Adams in diplomacy and statesmanship so overshadows his scholarly interests that his labors for the advancement of science have been neglected. From the diary one gathers that he would have preferred a somewhat different assessment by the biographers of his services to his country and to mankind; and in this self-judgment we must concur. A reconsideration of his work is warranted on another ground also. Adams lived in the beginning of the scientific renaissance in the United States and touched that great movement at several points; and he recognized, as not all statesmen do, the importance of the services that science and statesmanship may render to each other. He once wrote that "The people of this country do not sufficiently estimate the importance of patronizing and promoting science as a principle of political action." That seems to mean that aid to the increase and diffusion of scientific knowledge is a function of government; and that government should operate upon the fullest obtain-

[1] Boston, Little, Brown and Company, 1932.

able knowledge of nature and human nature. Was not this a prophetic vision of the "brain trust"?

Public employment left Adams slight leisure for the prosecution of scientific interests. Once "in Mr. Bussey's garden in Boston" he served as the amateur helper of Nathanial Bowditch in the observation of a solar eclipse; and he kept in sufficiently close touch with astronomy to have confidence in his own judgment that Bowditch's "Navigator" was "a perfect treatise of practical astronomy." He had a part in the establishment of three observatories, at Harvard, at Washington and at Cincinnati. In the second place, his labors to assure the integrity of the Smithsonian bequest and for the creation of the institution constituted a national service. And his report to Congress on weights and measures has not ceased to receive the encomiums of scientists and publicists alike.[2]

The report upon weights and measures occupied Adams intermittently, from the Senate resolution of 1817, for a period of about four years; but this was not the beginning of his interest in the subject. Five years earlier, during the Russian mission, he was occupied with the French writers in the field, especially Paucton. He noticed that Paucton was led to study weights and measures from an initial desire to improve agriculture, but the accessory became the principal pursuit and he produced his "métrologie primitive." "This is too much the progress of all my studies," he adds; "but I shall never produce a metrology." He came closer doing so than seemed possible in 1812. The preparation of his report was "a fearful and oppressive task" made so by the fact that "all the power and all the philosophical and mathematical learning of France and Great Britain" had been expended upon the subject. What under the circumstances could one man do? He might have submitted an a priori opinion or a pro-forma state paper, prepared by clerks.

What Adams did was to study the subject both from its beginnings and its foundations; and to write, after careful research, a treatise historical and philosophical as well as practical. Its great distinction is that weights and measures are considered not only with reference to the nature of things but also to the nature of man, his abilities, habits and institutions. Adams attempts to trace the origins of these instruments from primitive times and early society. He compares the suitability of the decimal arithmetic of tens and tenths, with a binary or a duodecimal system, not merely for computation but for the practical handling of material things. He reviews the historic difficulty of establishing uniformity by law; notices that the power of a law is limited to the legislator's dominions, while trade and science are international; and concludes that the province of law over weights and measures is not to create but to regulate. He traces the legal history of weights and measures in ancient and in modern times, and in the latter he devotes special attention to England and France. He introduces at this point an extended and an appreciative history of the "sublime effort" of France to develop a decimal, that is, the "Metric" system which should be founded in external nature, scientific in construction and regular in form and nomenclature. When he came to consider the metric system as a practical instrument in commerce he was less appreciative; and he failed to consider it as an instrument in science except at its weakest point, the measurement of the circle and of time—features which had already been abandoned when he wrote. To understand his position we need only remember that to him the most important object seemed

[2] Report of the Secretary of State upon Weights and Measures. . . . February 22, 1821. 135 pp. plus appendices, 100 pp. House Doc. 109, 16th Cong., 1st Session (1820–21); also, Senate Doc. 119, 2nd Session of same Congress.

to be universality in the use of any system that might be adopted rather than its symmetry, its natural base or other ideal considerations; and that the metric system, though adopted by the government, did not come into general use even in France until after the date of his writing. His report has given comfort both to the enemies and the friends of the metric system.

The practical result of the report was nil; and in this there may be a fairly fundamental criticism, since its purpose was a practical one. Of its two main conclusions also, the second is now known to have been erroneous. Those conclusions, expressed in the form of recommendations to Congress, were: That for the present the English weights and measures should be retained without change, but that correct standards should be deposited with each State; and that Congress should attempt to secure a concert of nations as the only practicable agency for the adoption of a permanent and uniform system. The present wide use of the metric system has, of course, come about by a piecemeal process. But for most of the errors of opinion and some of fact in this celebrated document Adams can not be held responsible. We cite one or two. He did not know that Mechain had introduced an error into the measurement of the degree upon which the metric system is based and that its natural base is, therefore, a myth. He speaks of "the problem, hitherto unsolvable by man, of squaring the circle." It was in 1882 when Lindemann showed that no solution is possible. Again, Adams wrote: "For all the transactions of retail trade, the eighth and sixteenth of a dollar are among the most useful of our coins; and although we have never coined them ourselves, we should have felt the want of them, if they had not been supplied to us from the coinage of Spain." Such minutiae, interesting mainly as showing that the report has its own date written plainly upon it, serve by contrast to emphasize the industry and acumen which were required to produce a classic in American metrology by a Secretary of State.

On the day when Adams despatched his report he wrote in his diary that he might not again have time to prepare a scientific monograph. And although this fear was realized, his work as a promoter of science continued, for we should include under that title those who aid in the establishment of scientific institutions or who, in any way, to quote the words of James Smithson, further "the increase and diffusion of knowledge among men." Adams had a large part in securing the Smithsonian Fund and guarding its integrity. As chairman of the House committee to whom the matter of its application was referred he rendered valuable services for the whole ten-year period during which ideas were being matured, crack-brained schemes were warded off and public interest was aroused. Anxious both for the promotion of science and for the honor of the country and armed with only such faith in his followers as his grim political experience had inspired, Adams feared that the trust might be wholly dissipated by fraud or unwise investment or might be applied to useless objects. But if we mean to recall that his fears rose almost to the level of an obsession we must also remember that they were not groundless. All this can be studied in the diary and in the well-nigh exhaustive collection of documents bearing upon the founding of the Smithsonian Institution which was made by W. J. Rhees. Of Adams' efforts it may be said that they were directed to acceptance of the trust by Congress in the first place; against the inauguration of hasty, immature plans, which were proposed in numbers; and to bring it about that the funds should not be invested in state bonds as at first but should become a permanent obligation of the United States Treasury.

To be sure he did not get his astronomical observatory, "to be superior to

any other devoted to the same science in any part of the world.'' Secretary of the Treasury Spencer once told him it was because the whole country was laughing at his designation of observatories, as ''lighthouses of the skies.'' But the Government did establish the Naval Observatory in 1843 and the Smithsonian Institution in 1846; and Adams' agitation had a useful effect upon both developments. It was just the time when the first permanent observatories were beginning to appear in the country. Winthrop and Rittenhouse and even Bowditch, who was not, however, primarily an observer, had none. In 1823 Adams had subscribed one thousand dollars for an observatory at Harvard, but the subscription could not be filled and the scheme failed. Less than a decade later and just as Adams entered upon the last phase of his life as a Representative in Congress, the building of American observatories began and increased until it became an educational and scientific trend, almost a fashion. Within a very few years of each other teaching observatories were established at Yale, at Chapel Hill in North Carolina, in Williams College and in Western Reserve near Cleveland and most distinctive of all in the new Philadelphia High School planned by Alexander Dallas Bache. In the West the center of the greatest interest in astronomy was at Cincinnati, and some work had been done by Dr. John Locke, who had even gone to Europe for information and instruments. The fruits of these efforts were gathered by Ormsby Mitchell who from the beginning of his connection with Cincinnati College extended his activities far beyond the boundaries of his professorship into work as a consulting engineer and a teacher of engineering. A newspaper of that day reports the arrangement by which ''Each of the professors will be at liberty to receive pupils, in his own branch, as irregulars. Under this permission, Professor Mitchell will forthwith organize a class in Civil Engineering, of which his regular pupils will likewise be members. To afford opportunity for practice in this important study, the professor will be allowed a vacation of four months in the year, during which he will be in the field with his students, engaged in actual engineering.''[3] To arouse the public interest in astronomy Mitchell resorted to lecturing, a form of instruction of which, as Lyell remarked, the Americans were very fond. The remark applied very well to Cincinnati, and Mitchell's lectures in particular were so popular that he raised the money for an observatory in that small western town. ''If the public support, based on public interest,'' said Newcomb, ''is what has made the present fabric of American astronomy possible, then we should honor the name of a man whose enthusiasm leavened the masses of his countrymen with interest in our science.''

Ormsby Mitchell no longer needs an introduction,[4] but it was on June 22, 1842, that Adams noted in his diary: ''Mr. Mitchell is a professor of mathematics of Cincinnati where he delivered last winter a course of lectures, he says, to three thousand persons, and he kindled such a passion for astronomy in that city that they have formed an astronomical society, with stock in shares of twenty-five dollars each, and have raised a fund of thirty thousand dollars to erect and furnish an observatory, for which purpose he is now going to England.'' Evidently Mitchell was himself quite a promoter and Adams did not like him at first. Besides the eloquent ''he says'' of the sentence quoted above the diary says: ''There is an obtrusiveness of braggart vanity in the man, which he passes off for scientific enthusiasm, and which is very annoy-

[3] *Cincinnati Daily Gazette*, October 19, 1836.

[4] An account of him is F. A. Mitchel's ''Ormsby MacKnight Mitchel Astronomer and General, a Biographical Narrative,'' 392 pp., Boston, Houghton Mifflin & Co. 1887. The spelling of the name used in the text above, seems to have been the contemporary one.

ing"; and Charles Francis Adams, editing the diary, calls this "Scant praise for Mitchell"! A year later Mitchell was back to see Adams, this time at Quincy, with letters, resolutions and an urgent invitation from the Cincinnati Astronomical Society to lay the cornerstone of their new observatory and to deliver an oration on the occasion. During the autumn the seventy-six-years-old statesman may be seen at his desk attempting to compress a history of astronomy into an address. "My task," he wrote, "is to turn this transient gust of enthusiasm for the science of astronomy at Cincinnati into a permanent and persevering national pursuit, which may extend the bounds of human knowledge and make my country instrumental in elevating the character and improving the condition of man upon earth. The hand of God Himself has furnished me this opportunity to do good. But, oh, how much will depend upon my manner of performing that task!"

After a cold, uncomfortable journey of thirteen days, traveling alternately by carriage, railroad train, steamboat and canal-boat, he reached Cincinnati on the eighth of November (1843). The oration upon which he had been working for more than a month was yet unfinished; it was incomplete at one when he retired, and he rose at four to finish it. The ninth was a day of pouring rain and as he tried to speak at the cornerstone-laying there stretched out before him not a sea of faces but a concourse of umbrellas apparently floating on a sea of mud. The next day came the oration, which was well received. He remained for several days. Naturally the wealth, position and talent of Cincinnati crowded about him and fêted him—Judge Burnet, Thomas Corwin, Bellamy Storer and Nicholas Longworth, who, Adams learned, was the especial patron of the observatory. Back in Washington for the opening of Congress he wrote in his diary:

". . . The people of this country do not sufficiently estimate the importance of patronizing and promoting science as a principle of political action; and the slave oligarchy systematically struggle to suppress all public patronage or countenance to the progress of the mind. Astronomy has been specially neglected and scornfully treated." Was he thinking of the derision which greeted his "lighthouses of the skies"; or did he think that astronomy was scorned above other sciences because he had stood out as her special champion? The diary continues: "This invitation had a gloss of showy representation about it that wrought more on the public mind than many volumes of dissertation or argument. I hoped to draw a lively and active attention to it among the people, and to put in motion a propelling power of intellect which will no longer stagnate into rottenness. I indulge dreams of future improvement to result from this proclamation of popular homage to the advancement of science, and am willing to see my name perhaps ostentatiously connected with a movement to which I so long and so anxiously strove to give an impulse in vain."

Is it too much to ask of a biographer that he shall read the great diary, extensive as it is; and, having read, that he shall duly ponder the many pages upon which the scientific interests and activities of John Quincy Adams are written at large? Having done so, he will recognize in Adams a scientist-statesman who saw that it is an important duty of government to patronize and promote the increase of knowledge among men. If now such a biographer will have the vision to see and the courage to present the facts as they are, the results should be salutary even though, comparatively, the glory of the Monroe Doctrine might be dimmed a little. Adams might say to his biographers, as Cromwell is reputed to have said to his artist: "Paint me as I am."

PARASITES, FRIENDS OF MANKIND

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A FEW years ago I attended a lecture in which the speaker prefaced his remarks with the statement, "Nobody loves a parasite." This is undoubtedly true. Not only do parasites fail to awaken affection in our breasts but, I fear, we are inclined even to despise such of our fellow organisms as have adopted this method of gaining a livelihood. The inference is, of course, that we consider ourselves to be, in some respects, superior to parasitic forms of life.

When we view the matter impartially, however, we can hardly stigmatize a parasite, which obtains all its nourishment from a single host, as a more serious biological offender against its fellow organisms than are catholic predators, such as ourselves.

Man, beyond a shadow of doubt, is the most abhorrent exploiter of all forms of animal life that the earth has produced. He searches the entire surface of the globe, the depths of the ocean and as far upwards as he can reach towards heaven in order to obtain victims that will satisfy his predatory appetites.

Members of nearly every phylum in the animal kingdom find their way into the insatiable stomach of man. The few that escape do so because he does not relish the flavor of their flesh or because, while living, they appear to him to be somewhat repulsive. We eat oysters with avidity, provided we obtain them in a month that contains an R. Few of us, however, have more than a hazy idea of the manner in which oysters pass their days or even of the significance of that qualifying R. In order that we may continue to enjoy the gustatory pleasure evoked by these slippery bivalves it is perhaps as well that we continue to make our first acquaintance with them in company with cracked ice and labelled, "60¢ a pint."

On the other hand, we are all more or less familiar with caterpillars during their lifetime. In this stage of their career the majority of us consider them to be so repulsive that the bare idea of eating one is accompanied by an involuntary shudder. The old riddle, "What is worse than finding a caterpillar in the apple you are eating?" with its answer, "Half a caterpillar" makes too universal an appeal to need further comment. This, despite the claim that caterpillars, when properly prepared, are very palatable and of undoubted nutritive value. Somehow I feel that man, the predator upon mammals, birds, fish, amphibia, crustacea, arachnida and mollusca, falls short in his glory as the consumer, par excellence, of his fellow creatures by this unfair discrimination against insects.

Still more appalling than is our widespread predatism are some of the methods whereby we daily exploit our more or less distant relatives. What term would we invent to describe any animal, other than ourselves, which consistently removed new-born young from their mothers and, thereafter, stole for its own use the almost sacred maternal fluid that is produced solely for the nutrition of their helpless offspring? Such behavior would be considered as scarcely an approved topic for conversation in polite society.

Some of us prefer our eggs as omelettes, as a soufflé or merely "sunny side up." However we may disguise them, we consume almost daily the un-

formed young of a fellow traveler along one of the divergent paths of life.

These examples should serve at least to indicate that parasitism is a very mild form of exploitation as compared with the types of predatism that are practised regularly by the most "humane" among mankind. If, in addition, you care to contemplate the refined cruelty of cramming and of paté-de-foies-gras I think you will agree that, in the whole realm of nature, man, least of all her diverse creatures, has cause to point the finger of shame at any other form of life which lives, in any manner whatever, at the expense of its relatives.

It is not, however, my purpose to blacken the face of man in comparison with strictly parasitic forms of life. It would not, indeed, be difficult to show that he himself evinces many tendencies in this direction in addition to his other crimes. Rather, taking man as he is, I wish to establish the fact in your minds that we have cause at least to be grateful to many parasites. More than that I will not ask. Love is, perhaps, too intimate an emotion.

The meaning of the word "parasite" is extremely vague. Restricted originally to a class of human society, its application has been widened to include a most heterogeneous variety of biological relationships. What exactly do you or I mean by a parasite? Any standard dictionary gives six or seven alternative definitions. There are several varieties of social parasites and still more numerous nutritive parasites. To the biologist there are many more types than those that find their way into a dictionary. If we consider but one form of life, namely, insects, we find that they exemplify several different degrees of nutritive parasitism.

First of all there are those which spend their entire lives feeding on the surface of a host animal. Lice are examples. Since they never enter their host they are termed "ectoparasites." Others, as larvae, are true endoparasites. These live entirely within a host. They may or may not feed at all when, as adults, they subsequently live an independent life. Common examples are the warble-flies of cattle.

A little further removed towards independence are the so-called parasitic wasps or ichneumonids. The majority of these live, during their larval life, within other insects. As adults, many feed exclusively on pollen and nectar from flowers. These, certainly, are less truly parasitic than are lice. Some writers prefer to classify their activities by the non-committal term of "parasitoid."

The ill-famed bedbug imbibes from the nearest victim at mealtimes and then retires to its own quarters. Should these be included in the category of parasites? If so, shall we draw the line between them and the flea which, when immature, finds its food on the ground and only when mature relishes a meal of blood? It is probable that the majority of people would consider the flea to be truly parasitic, despite its virtuous early life. If then we include fleas shall we widen this term by the addition of mosquitoes? As larvae these insects feed exclusively on material of vegetable origin. Even after they have reached maturity the bulk of their nourishment is obtained from the same source. Every male dies as he has lived, a strict vegetarian. All that a female demands from her distant relatives is an occasional draught of blood. This appears to be necessary for the development of her eggs. For the rest of her career she, too, sips nectar from flowers by the side of her consort.

When such a diversity of relationships are called by the same name, and when we consider that a dozen additional types of exploitation could be added if we seek elsewhere, it is no won-

der that the word "parasite" has a somewhat nebulous meaning. In its strictest sense it would seem that the term, when applied to nutritive relationships, should be restricted to any organism that obtains all its nourishment from a single host animal. All others are, in reality, types of predators. Since, however, all are variations of the same phenomenon we need not, for the purposes of this paper, draw very hard and fast lines between parasites and predators.

The true parasite rarely kills its host in obtaining its dole of nourishment. It is, obviously, a remarkably bad stroke of business on the part of a parasite to destroy the source of its daily rations. It is even bad business to make the host aware of the fact that it is being exploited. From a biological point of view the most successful parasite is the one that can obtain its nutriment with the least discomfort and detriment to its host. The mosquito which obtains her draught of blood from your neck without your being aware of the robbery stands a better chance of raising a family at your expense than does her cousin whose pilfering is proclaimed by a vicious stinging sensation.

The bites of the so-called "wild" mosquitoes, which inhabit sparsely peopled regions, are far more painful than are those of their "domesticated" relatives, which inhabit those parts of the earth that have been densely populated for many human generations. The present inhabitants of the latter regions owe a debt of gratitude to their forebears who, through ages of unremitting slapping, have selected strains of mosquitoes that obtain food with the minimum of discomfort to their hosts.

We, in our generation, do something for posterity every time we kill a particularly vicious mosquito and ignore the activities of her milder mannered sisters. To a trifling degree we throw the balance for survival in favor of strains that cause the least annoyance to man.

The relentless laws of evolution continually weed out as unfit to compete for immortality, through the medium of their descendants, those strains of any parasite that are less considerate of the welfare of their hosts than are their near relatives.

A perfectly adapted parasite causes no appreciable damage to its host apart from draining from it a modicum of nutriment. This stage of perfection, probably, is rarely attained. When it is, some writers term the relationship thus established between host and parasite "symbiosis"—living together. Many insects, among which the most familiar to us is the ubiquitous cockroach, carry from generation to generation colonies of bacteria embedded deeply within their bodies. A certain number of these are transferred from the parent's body to every cockroach egg long before the latter is laid. What effect these bacteria have on the lives and the happiness of cockroaches we are unable to say. Every cockroach contains them, and we know of no way of removing them. We do know, however, that certain hosts obtain a direct benefit from their ever-present parasites, and that they ultimately become dependent upon them for their very existence. When this is the case we pass from parasitism, through symbiosis, to "mutualism," or the interdependence of the two organisms. Such, for example, is the relationship between white ants and the luxuriant fauna of protozoa which invariably inhabit their alimentary canal. These can be killed, without otherwise affecting the white ant, by subjecting the latter to an atmosphere of oxygen under pressure. Deprived of its one-time parasites a white ant can no longer digest its normal diet of cellulose and it dies of starvation in the midst of plenty.

It is even postulated that our own red

blood corpuscles may be the outcome of an invasion of the blood of our distant ancestors by parasitic protozoa. These examples, to which many others could be added, are of considerable biological interest. They show that parasites can, if given a sufficiently long period of adaptation to their hosts, be modified into most valuable companions. As is the case in many walks of life, it is the novices that cause the greatest havoc.

Only under most exceptional circumstances can predators prove to be temporarily advantageous to the welfare of their victims. Man, by protecting his intended victims from other forms of life that desire to share the feast with him, may prolong the lives of some of his domesticated animals. Loud, however, are the complaints when he errs by stretching the span of life beyond that of gastronomic perfection.

I have yet, however, to vindicate my premises to the effect that parasites are actually the friends of mankind. I propose to attempt so to do, though I anticipate that few of you will agree with me in my efforts to show that our own specific parasites are more beneficial than otherwise. In what I am about to say I would ask you to think of mankind as a race rather than as a collection of individuals. To the individual his parasites are naturally unpleasant and deleterious. Attempts to consider them otherwise have not met with marked success. Hermits of old believed with religious zeal that all things on earth were created for the good of man. "All things" necessarily included human parasites. These were satisfactorily fitted into the creed by accepting the dictum that they were created to mortify the flesh, which is the sinful part of man. Clothed in their unwashed and overpopulous garments these ascetics had ample opportunity to praise God for the activities of His humble workers. Fortunately for our bodily comfort, the religious attitude towards parasites is less heroic at the present day. We have no hesitation in employing every means at our disposal to protect our bodies from all kinds of marauders.

When, however, we consider mankind as representing a mammalian species, with all the attributes of other biological organisms, we may discover, in the parasites of his race, a valuable asset in maintaining some of his most cherished ideals.

I need hardly remind you that all forms of life over-reproduce. To this general biological law man is no exception. Nearly 150 years ago Malthus showed that, under favorable conditions, human populations tend to double in numbers every 25 years. Who among us desires to live under any but favorable conditions? This rate of increase was exceeded in the early years of the exploitation of our own continent, at a time that preceded nearly all the more important life-saving and life-prolonging discoveries. It is obvious, however, that the population of any part of the world can not continue to increase indefinitely. Theoretically it can do so only until such times as its demands equal its supplies. Thereafter it must remain moderately constant. This point being reached, as Malthus pointed out, the checks to further increase come under two general headings—preventive and positive.

We need not dwell for long on preventive checks. These have undoubtedly been powerful in the past in crowded communities. Some people believe that they will become increasingly effective and that they will solve the entire problem of population stability. Such a solution is, of course, biologically unsound, and is the first step in the direction of race deterioration and possible extinction.

From the far distant and misty past, when life first became a reality on earth,

down to the present day, all living things have, with reckless abandon, produced a continuum of generations, in every one of which the individuals have been far in excess of the numbers that can survive. From this superabundance nature, as unremittingly, has made her selection of a small minority that she judges to be fit to fulfill their destiny of continuing this over-reproduction. The vast majority she sweeps into the discard. Their lot is to perish miserably, or otherwise, provided their demise be expeditious. By this relentless persecution, only, has nature improved her diverse forms of life and has brought to perfection their various adaptations for competing to-day with their all-too-numerous relatives. Man is but one of these many competitors. Can he afford voluntarily to set aside the factor that has been paramount in bringing him to, and maintaining him at, the physical and mental level he has reached? When man ceases to over-reproduce the laws of race improvement will cease to operate in so far as he is concerned. He will stagnate, from an evolutionary point of view, in a world in which all other forms of life are pressing forward to greater and more varied destinies.

I am, however, of the opinion that man, in common with his less intellectual relatives, will continue to over-reproduce and therefore to progress as a species at the expense of those individuals in each generation which are least fitted to be men.

Without further consideration of preventive checks we can turn our attention to the positive checks—those which remove individuals after birth, but before they have contributed their full quota of offspring to the overnumerous ranks of the rising generation. I think most of us will agree that, in the past, these have been emigration, starvation, disease and war. Of these starvation, or the fear of it, has played a prominent part in engendering the other three.

The world over, human populations have been frequently in danger of reaching saturation point, till one or other of these checks temporarily relieved the situation.

The saturation point of many of the more densely populated regions of the earth has been greatly increased by the discovery of areas that were more thinly populated because they were less expeditiously exploited. Numerous emigrants to these regions have relieved the pressure at home and, in addition, they have effectively exploited the possibilities of the land of their adoption. Here they can produce far more of certain necessities to life than they, themselves, require. The development of rapid world-wide transportation enables them to pour their surplus into their native land. With this influx of supplies the saturation point of these countries has increased by leaps and bounds. It now far exceeds the possibilities of their own resources. The discovery of America by white men has increased the world population by possibly twice as many individuals as can be numbered among the 180 millions who inhabit it.

In the history of the human race this can, however, be but temporary. The day must come when all humanity will weep with Alexander, and with far more reason, because there are no more worlds to conquer. Already we see the first signs of this on our continent. The rapidly increasing progeny of earlier arrivals are already putting up the bars against their relatives in overcrowded countries who would follow in their footsteps.

With the diminution of this outlet for surplus population the day draws appreciably closer when man will have reached his mean of maximum abundance over the entire earth. He can no more escape this destiny than can any other form of life. Wars, disease and starvation have combined in putting off this day. Man is setting his mind as

never before to mastering all these checks to this steady advance towards the inevitable. What will be the result if he succeeds in his endeavors?

Whatever the size of the family, once the mean of maximum abundance is attained, an average of two only can survive. Darwin made this abundantly plain many years ago, but man, in various parts of the world, continues to struggle against this law. Among the Chinese, in a land the population of which had reached its maximum centuries ago, despite many wars, much disease and appallingly wide-spread starvation, every man still feels that he must have at least twelve children in order that two may survive to do homage to his old age. The fate of the ten who are doomed to perish at an untimely age appears to us to be tragic. They merely exemplify nature's universal method of procedure; over-reproduction in order to assure adequate survival.

Fluctuating as is the mean of maximum abundance that the laws of nature allow to any species, a marked increase during any abnormally favorable period, be it long or short, inevitably spells additional misery to all succeeding generations till the population is, once more, reduced to its proper level. During this readjustment period nature, more drastically than at other times, weeds out for survival the few that are the best equipped to vanquish their most implacable rivals—brothers, sisters and cousins—for all of whom there is no longer room on earth. The more prolific the animal, the more drastic is the mortality in every generation. The majority of insects lay 300 eggs. Since, of the insects that should hatch from these, an average of two only can survive, 298 (*i.e.*, 99.3 per cent.) must perish without reproducing in order to maintain their *status quo* with other forms of life. At times, nature, for a period, relaxes her persecution of some insect and allows the mortality to drop to, let us say, a mere 90 per cent. It is not long thereafter that man cries as did the prophet Joel, "That which the palmerworm hath left has the locust eaten; and that which the locust hath left has the cankerworm eaten; and that which the cankerworm hath left, has the caterpillar eaten."

But nature never fails to take her revenge at the expense of future generations. She raises her harvest to 99.9 per cent., or higher still, if needs be, in order to force her upstart offspring back into the niche that she has prepared for it by her infinitely slow but perfectly adjusted laws of maximum survival.

These laws apply, with no less rigidity, to man. Slowly as he may increase his numbers as compared with his more lowly relatives, the difference is only in degree, not in kind. If in the present generation the total world population is increased, future generations must pay the bill.

The statement that all men must die is axiomatic. To this must, however, be added the corollary that a large percentage must do so before they arrive at the stage of parenthood. The grim harvester of the childless is implacable. As the vacant spaces of the world fill up he becomes increasingly insistent in his demands. Struggle as man may to avoid the inevitable, there is no escape. One or other of the pruning knives must fall. Which of these, starvation, war or disease, is the least detrimental to the future development of the human race? To this trio we might add, with increasing significance, a fourth—namely, "accident." The auto is already assuming a prominent rôle in holding populations more nearly to their *status quo* in many parts of the world.

Starvation, war and disease. All have had their share in the past in regulating human populations. All will, doubtless, continue to do so in the future. Is it

not as well then for us to consider each in turn and to discuss its relative merits? Each by itself is ghastly. One, however, that is the least so, or one that shows some redeeming feature in that its operation tends to improve the caliber of the survivors, is a veritable haven of refuge from its more devastating competitors. Our effort at the present time is, quite naturally, to avoid all three of them for ourselves and for our children. We are willing to let future generations decide for themselves to which they will submit when nature presents her bill for the overdraft. In this endeavor mankind reveals his fundamental selfishness.

Among primitive races, dwelling in confined areas, starvation has doubtless been a potent pruning knife for trimming the family tree. It must be borne in mind, however, that this is nature's last resort, which is employed only when all else has failed. Whole nations have, in the past, been decimated by starvation. Can any one imagine a similar occurrence among modern "civilized" communities? Could you postulate a democratic nation content gradually to starve when neighbors have ample? Commercial rivalry may be a somewhat distant forerunner of actual starvation. Who would deny, however, that this has been the cause of many recent wars? The desire for adequate nourishment is so deep-seated in every animal that no biological urge can arouse enmity more rapidly among fellow creatures than its denial. I believe that starvation will never again play a direct and widespread part in maintaining the *status quo* of populations. It will always be preceded or accompanied by war, whether in the form of individual killings, revolutions or trumped-up wars of national honor against neighbors. Democracy has given the hungry an equal voice with the well-fed in expressing his opinions and, through the medium of the vote, in enforcing them. Whatever might be the ultimate effects of starvation on the race they are subservient to those produced by its consort, war.

War is distinctly unpopular in the minds of the majority of people at the present time as an acceptable means of removing surplus populations, and rightly so. In the past it has been man's most favored method of regulating population difficulties. It has appeared to be the most logical means for adjusting the difficulties that arise when demand is somewhat in excess of supply. It may be claimed that many wars in the history of mankind have not had their origin in actual or imminent shortage of supplies. There can, however, be no argument but that every war has resulted in the reduction of population. They have, to that extent, served their purpose and have obviated the necessity for later wars in which self-preservation would have been the sole motive.

War as a check to overpopulation is, however, more biologically unsound than is restriction of birth. Truly it has been said that those who live by the sword shall die by the sword, if this be interpreted as applying to communities and not necessarily to individuals. No community, which in the interests of self-preservation makes war on its neighbors, would hazard the risk of sending its weaklings, either physical or mental, to bear the brunt of the fray. The best they have in manhood goes forth, many of them never to return. To their weaker brethren falls an undue share in assuring race continuity. It is inevitable that this type of selection, when indulged in frequently, must lead to race deterioration. The day will surely come when the community, deprived not only of those who lived by the sword, but also of those who would have been their progeny, will die by the sword of a more favorably selected strain of neighbors.

Although there is to-day an increasing realization that war is unethical, uneco-

nomical and that it outrages all principles of beneficent race selection, I, for one, can not believe that it is a passing phase of human activity. Human nature can not be remodeled in a single generation, and only very slightly in a hundred. Fashions, admittedly, change with every season. Twenty years ago men who, for one reason or another, did not reveal any eagerness to go out and fight were liable to be decorated with a white feather at the hand of a feather-brained girl. How fashions have changed in twenty years! Fashions are, however, only a veneer that but ill disguises the true nature of the object beneath. From the dawn of life on this earth till to-day man, or his ancestors, has fought his fellow men for his very existence and survival. Because your forefathers and my forefathers struggled ceaselessly against, and vanquished, the potential parents of myriads of other men and women, we and not they, inhabit the earth to-day. You and I are the product of aeons of bloodshed and hatreds. We may not feel very grateful for the legacy, but the parent who readily abandons her offspring in the interests of her neighbor's will never make a very powerful human appeal.

In the year of grace 1934, mankind, as he completes his million to the nth generation of internecine warfare, proclaims: "Every one of my myriad ancestors who, because he fought, survived to reproduce his kind was in the wrong. The world should have been peopled with the progeny of those who died at their hands, and I have no right to be here. Beginning with my million to the nth plus one, generation I declare myself purged from my hereditary taint. I am henceforth reincarnated. Incidentally, of course, all my neighbors are reincarnated also."

This is an excellent resolve. All success to his efforts! Surely, however, in such a quest he will need powerful friends. He looks to be rather a poor lost mite as he carves out his new destiny in a universe where brother has fought brother incessantly from the dawn of life to the present day in which amoeba still ingluves amoeba and the elephant trumpets over his dying rival.

Where, in such a world, is he to find friends who will aid him in his high resolve? Only, it would seem to me, in those allies that are always on hand to reap for him the supernumeraries of his kind, his own parasites, his diseases. Provided these supernumeraries are brought into the world at the same mad rate that they have been in the past, and evolutionary progress demands that they must be, somewhere must be found the harvester of the immature. Emigration and starvation have nearly run their course in making room for those who are left behind. Man, and may God prosper his resolve, is determined never again to lay his sickle to the superabundant harvest. Already he contemplates placing it aside and is drawing plans whereby it may be beaten into a cradle-rocker. Rather wisely, however, he is not putting his plans into effect just yet but is keeping it in the attic till he is assured that his neighbors are like-minded. A cradle-rocker is a poor implement to seize should the cry go forth, "Harvest or be harvested!" Have we sound reasons for believing that this cry has been heard for the last time on earth? For how long can man hope to live up to his new-formed ideals? The answer, I submit, depends chiefly upon the activities of his friends and enemies, his own parasites. If, with relentless insistence, they garner a sufficiently abundant harvest of the childless to assure that there is room for all that remain, then, and then only, it would seem to me, can man hope that neither he nor his neighbors will succumb to his hereditary instinct to fight for his own preservation and for that of his children.

This may appear to be a ghastly alternative to war. Surely it is infinitely preferable. Association with those who are struck down with disease tends, at all events, to bring out the best in human nature, sympathy and self-denial. Certainly not the adjuncts of war, enmity and brutality. War takes from us of our best, disease those whom we pity the most because they were not so blessed in physique as are the common run. Of course there are tragic exceptions. There are also exceptions in the case of war, but the general tendency of disease is to improve the race; that of war to deteriorate it.

There is no denying that war and disease have been the major regulating factors of human populations in the past. Provided the number of births continues to be in excess of deaths from accident or old age one or both must remain in office. For my own part I can not visualize a world (in which there is a measure of individual freedom of action) in which there is a perfected medical service and an absence of armies. Such concepts are mutually antagonistic, and no world can be, for long, large enough to contain both of them.

Bound as we are to fight those invidious enemies, the parasites of the individual, they yet constitute the most potent friends of mankind as a race in his groping towards brotherly love.

All honor to those who burn the midnight oil, who impair their own health and who imperil their very lives in their efforts to wrest their fellow men from the scourge of disease. Theirs is perhaps man's most lofty ideal, but, pray God, for the sake of mankind, that they be not too successful in their efforts.

Many of you may even yet feel that I have failed utterly to prove that parasites are, or ever could be, friends of mankind. If so, I regret that my proof has failed to convince you. It will be necessary, therefore, for me to bring forward conclusive evidence to the effect that you and I exist on earth simply by the grace of parasites. I would draw your attention for a few minutes to the debt we owe to those parasites which hold in check the numbers of our most insistent rivals—apart from our fellow men—the plant-feeding insects.

Ages before the ancestors of man had escaped from the ocean, mother of all life on earth, the dry land already teemed with insects.

It is probable that it was from the tidal shores of some Devonian ocean that a trilobite-like creature, for the first time in the history of animal life, not only succeeded in living out of water, but completed the emancipation of its descendants by depositing eggs that hatched without submersion. This lonely creature, ancestor of all insects, donated to these descendants all the dry land of earth from pole to pole. Overcrowded as was the ocean, there were as yet no competitors for the luxuriant vegetation that covered the vast mountains, valleys and plains of earth. Surely this insolent speck of animal life, by invading an entire new world, would be swallowed up in the very enormity of its undertaking.

Armed, however, with a good digestion and a superabundant fecundity it was not long—only a few millions of years—before its descendants were seriously overcrowding each other in every part of the earth that was habitable to them. By the carboniferous age they had acquired wings the better to escape from each other and to seek pastures new in which they might browse in peace. Even this phenomenal aid to rapid dispersal could counteract for but a time the menace of their own fecundity. The time must surely arrive when the demands of the insect population, in various parts of the earth, would be in excess of the vegetation that it could produce. By its very success insect life

was threatened with extinction, until this life took advantage of its own excesses. Certain groups of insects became adapted to feed upon their plant-feeding relatives. At first there were simply scavengers or predators, but later many of them developed into true parasitoids.

From that time onwards insects have never regained their status as the dominating form of life on earth. Popular magazine articles to the contrary, I, personally, believe that the age of insect ascendancy on earth has passed. It was terminated by the insects themselves when they learned to parasitize each other. Not only did this terminate for all time the possibility of any further marked increase in insect populations, but it made room for the safe invasion of the dry land by the ancestors of man and his relatives.

A marvelously adjusted balance was soon established between the abundance of those insects which still fed on vegetation and those which, as parasites, became dependent upon their numbers for their own numerical strength. This balance holds to the present day. It is not, however, a matter of very great surprise that there is still an intense rivalry between these one-time lords of creation and their comparatively recent competitor, man. Man is now beginning to realize that the most effective weapon he can employ in combating them is to call to his aid those all-powerful allies, their parasites.

Both the plant-feeding host insects and their parasites are capable of prodigious over-reproduction in every generation. Both, however, are held to about the same number from year to year on account of the abundance or the scarcity of each other. The host insects are prevented from increasing by the annual decimation of their youth by the parasites, and the latter fail to increase their numbers because they do not allow the host to become sufficiently abundant to provide dwelling places for any increase in their own families.

Vagarities in the climate of any year may, however, favor an unusually large survival of either host or parasite. If it be the host that is thus favored this automatically provides the parasites with opportunities to raise abnormally large families. The result is that the next generation of host insects have an unusually large number of parasites seeking their destruction.

We are all more or less familiar with outbreaks of plant-feeding insects. For a few years some species of cutworm or grasshopper gives a limited demonstration of its ability to increase in numbers. During this period we, their inevitable rivals, feel that we are most unrighteously cheated out of more than the 10 per cent. of the earth's produce that we still concede to our declining foes. Were it possible for a cutworm outbreak of world-wide extent to continue for half a dozen years, and for the initial rate of increase in population to be maintained throughout this period, there could be but one outcome in so far as man is concerned. He would be starved out of existence, unless perchance he discovered that he could satisfy the requirements of his body by eating fresh cutworms in summer and preserved ones in winter.

Insect outbreaks, however, do not last indefinitely. Parasites are not slow to take advantage of the increased number of their host in order to reveal their own powers of increase. By the end of the second year of an outbreak, at the latest, myriads of cutworms fail to turn into moths that normally would have laid their 300 cutworm-producing eggs. Instead they give rise each to a parasite, which is loaded with 300 cutworm-destroying eggs. Under such circumstances it can be but a matter of a few years before the outbreak has been terminated by them. Thus do man's allies and friends, parasites, prolong his lease of life on earth.

It is true that this relationship between the abundance of host and parasite is complicated by many interacting factors. Possibly it will never be thoroughly understood by man. We can, however, grasp its most salient characteristics. Furthermore, we can utilize this relationship to our own great advantage.

In 1843 a French naturalist, de Poitiers, made the then original suggestion that native predatory beetles could be utilized by man for the control of caterpillars in gardens. This was hardly a practical suggestion. We now know that it is only by importing parasites from distant countries that we can expect to obtain a marked benefit from interfering with their activities.

It was not until nearly 1900 that the exportation of insect parasites from one country to another had been proved to be an effective method in insect control. To the United States belongs the greatest credit in developing this, the most logical method for holding the numbers of injurious insects in check. The reason for this is, to some extent, due to the fact that here, more than in any other country, alien insects seriously menaced not only many phases of agriculture but, in addition, the natural beauty and the forest reserves of the entire continent.

Early arrivals from Europe soon discovered that the Indian had not been an expert in developing the fruits and other vegetation that were native to America. If they desired "improved strains" they had to import them from their home countries. This led to the extensive importation from Europe and elsewhere of fruit trees and bushes, of ornamental trees and shrubs and of the roots or seed of herbaceous plants. Unfortunately, on some of the vegetation that was brought to this country, there were occasionally a few eggs or other developmental stages of insects that normally fed upon it in the home country. All too many of these were able to continue their development in the new land. At the time no one realized the menace of this handful of undesirable aliens, and could hardly foresee that they would prove to be a greater detriment to agriculture and to fruit production in America than were the countless millions of insects that already inhabited the country. Never in Europe had insects, such as the codling-moth, the cabbage-butterfly, the gipsy-moth, the larch-sawfly, or the more recently imported corn borer, to mention but a few, done a fraction of the damage that they proceeded to do in eastern America. Not only did they ruin many of the imported plants, but, increasing in leaps and bounds, insects such as the larch-sawfly and gipsy-moth began the utter destruction of any native trees that met with their food requirements.

In Europe the larch-sawfly had been recorded as a somewhat inconspicuous insect that was occasionally found feeding on larches. There all interest ceased until it was accidentally imported into the Arnold Arboretum in Boston in 1882. In 1883 it had already spread to Canada. The following is a quotation from the report of the Dominion Botanist, Dr. W. Fletcher, which was made a few years later: "After three to four years of being stripped, the larches over millions of acres, and practically over the whole of eastern Canada, were almost wiped out. With this large destruction of its food plants the insect practically disappeared."

The history of the gipsy-moth in America since 1896, when some half dozen of its caterpillars escaped in the vicinity of Boston, is too well known to require a detailed repetition here. It will suffice to recall that, during the next forty years, their progeny devastated millions of acres of forest and ornamental trees. At the end of this period it appeared that, despite everything that

could be done, the brains of man were outmatched by the fecundity of the gipsy-moth. There was grave danger that it might gradually devastate the whole of the continent with the exception of northern Canada which, fortunately, lies beyond its climatic range.

Why should the gipsy-moth prove such a scourge in America? It was well known to those of us who passed our youth in Europe. There, it was just "one of the insects" of woodlands of which there were occasional outbreaks which might last for a year or two and then subside. Why, then, in America was this outbreak permanent until such time as it subsided simply because the caterpillars had destroyed everything on which they could feed? The answer, of course, is that, though the gipsy-moth had found a home in the New World, none of the parasites which normally live at its expense in Europe had managed to emigrate with it. By 1913, however, man had mastered the gipsy-moth, but his mastery was attained only through the medium of parasites.

When, after overcoming obstacles which, at times, appeared to be insurmountable, he succeeded in introducing from Europe several of its most important parasites the end of the gipsy-moth's reign of terror was in sight. It is true that the infested area continues to increase despite all direct efforts on the part of man to prevent it, but close on the heels of the caterpillars will follow its relentless parasites, whose sole business in life is that of decimating their numbers. Despite this increase in invaded territory the status of the gipsy-moth is changing from that of an unmitigated scourge to that of an additional, albeit unwelcome, insect that inhabits the woodlands of America. This is possibly the most decisive victory that man has won over his age-long rivals. It will be seen, however, that this victory was won, in reality, by parasites that man called to his aid.

More recently a portion of Ontario and of a few neighboring states has been invaded by the European corn borer. This insect, if left to its own devices, threatened to ruin the entire corn-growing industry of North America. Vast sums of money have been expended on mechanical methods and for poisons in an effort to prevent it from spreading to territory that is at present uninfested. Effective as many of these have proved to be, they are but temporary expedients; expensive and laborious stop-gaps that serve a valuable purpose until the parasites which have been hurried from Europe will assume the permanent rôle of holding down the population of the corn borer. Parasites, of course, will never exterminate the host insect, but, once they are established, their numbers will steadily increase at its expense till no further increase in the population of either is possible. Although the plant-feeders may still be present in sufficient numbers to cause serious damage there are henceforth definite limits to their destructiveness.

A somewhat different employment of parasites is now being attempted on the Canadian prairies. In recent years the wheatstem-sawfly has ruined thousands of acres of wheat. This is a native insect. It is not, therefore, in the same class as is an imported pest. Before the days of agriculture it was a rather rare insect on the prairies. How are we to account for its phenomenal increase? The answer is that we have imported a foreign plant which this sawfly inhabits in preference to its native home. The sawfly lived originally only in the stems of native grasses. Now it lives in the stems of wheat.

Parasites that attack its grubs in grass-stems fail to do so very effectively when they inhabit wheat. Thus, by a somewhat unexpected route, the sawfly has escaped from its parasites, and man, as is usual under such circumstances, is a heavy loser. What can be done in a

case like this? We know of no very satisfactory method for forcing the recalcitrant Canadian parasites to attack the sawflies that inhabit European wheat. In Europe there is, however, a close relative of our American sawfly that also lives in wheat. It never does very much damage in England, because there it is in a state of equilibrium with a number of parasites which attack it in wheat stems. If we were to bring some of these English parasites to Canada would they attack our Canadian sawfly grubs in wheat stems here? Could they reduce its population to the insignificant numbers of its English relatives? It is too early to hazard an answer to these questions. Parasites have been brought over and have been liberated here. Some of them have succeeded in surviving our severe winter, but we do not, as yet, know how successful they will be.

I have selected a few somewhat spectacular examples of the use to which man is learning to put parasites. This art is as yet in its infancy. However successful the results may be, they are of infinitely minor importance when compared with the debt we owe to the ever-present parasites of our thousands of native species of plant-feeding insects. The majority of these are so rigidly held down to small numbers year in and year out that we never even trouble our heads about them. Under certain combinations of climatic conditions a few of them, unfortunately for us, manage occasionally to elude, to some extent, the attentions of their parasites. When this occurs the entomologist becomes, for the time being, a person of considerable importance. People have even been known to listen to a complete ten-minute address by him on the radio, under the stress of the situation.

During these "outbreaks" losses may run to several millions of dollars in addition to the large sums of money that are expended on control measures. Usually only one, or at most two, insect species are concerned in an outbreak. Picture the situation, however, if all species of plant-feeding insects were liable to occur in outbreak numbers on account of some vagarity in our climate. The fact that our native parasites do keep down the numbers of practically all of them, year in and year out, despite every variation in climate, doubtless reduces your respect for entomologists, reduces the number of highly paid positions for entomologists and has given me time to prepare this paper which I am inflicting on you.

Despite these manifest failings, I still claim that parasites have every right to your respect and that they are, more than otherwise, the friends of mankind.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

ELECTRON OPTICS

By Dr. C. J. DAVISSON

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In the olden times when the filaments of incandescent lamps were exposed to public view in bulbs of clear glass, it was possible to make quite an interesting experiment with a magnifying glass. By holding the glass in the right place an image of the filament could be formed on the wall of the room—a small bright one with the glass held near the wall, and a large pale one, which jumped about a good deal, with the glass held near the lamp.

It is quite well known, of course, how these images are produced, but that won't stop me from telling you. It's done by refraction. When a beam of light passes from air into glass its direction is changed—it is turned through a certain angle and the angle isn't always the same. It is zero when the beam comes straight at the glass surface and gets larger as the light comes at the surface more and more obliquely. So we have a way of turning a beam of light. We hold a piece of glass, say an inch thick, across a beam of light—if we hold it straight across, the light goes straight through without turning. If we turn the glass so the light meets the surface obliquely, then the beam is turned as it passes into the glass. It is turned in the same direction the glass has been turned, only not so far. But then when it comes out the other side it gets turned back again—so that all that has happened really is that the beam has been moved over a bit. But now suppose that instead of a plate of glass we have a wedge-shaped piece—the sides not parallel—then the two deflections won't just compensate one another as they do when the sides are parallel, and the beam will leave the prism, as a wedge-shaped piece of glass is called, in a different direction. It will have been deflected away from the thin edge of the wedge. Now, you see, the thicker the wedge the greater the deflection, because, regarded as a wedge, the glass plate with parallel sides was the thinnest possible—and then the deflection was zero. And here, of course, by thickness we mean the angle between the two faces and not the thickness in inches, which for a prism would be a bit vague.

Now suppose we look at our magnifying glass. It has two rounded surfaces—portions of spheres as a matter of fact. What happens when we hold it in front of our old-fashioned lamp bulb? Well, consider the light which is coming from one single point on the filament—a part of it is coming straight at the center of the lens—if it gets a slight deflection as it passes into the glass, it gets a nearly equal one in the opposite direction as it passes out because if we were to hold stiff cards against the lens, one where the light enters and the other where it leaves, the two cards would be nearly parallel—so far as this particular bit of light knows, it has passed through a glass plate and it isn't deflected. But what about other beams or pencils of light from the same point on the filament? We look at one which strikes near the edge of the lens. If we do the same trick with the cards we find that they make quite a considerable angle with one another—so this beam of light

is deflected quite a lot—away from the edge and so toward the beam that went straight through. Now perhaps you see how it is—the more the beam misses going through the center of the lens, the more it is deflected towards the center—all these beams which passed through the different parts of the lens have a chance of coming together again somewhere beyond. Well, that's just what they do; they all come together at a point and this point lies on the beam which passed through the center of the lens and was not deflected, because this is one of the whole collection of beams which comes together. So, you see, all the light which started from a single point on the filament and passed through the lens has come together again at a single point beyond the lens. And this goes from all other points on the filament which send light to the lens—each of them has its own light brought together in a point or focus and all these foci taken together constitute the image of the filament which appears on the wall and so impresses the children with our cleverness.

Now I am really supposed not to be talking about light at all but about electrons. The quickest way of getting over where I belong is to say that the filament of the lamp sends out not only light but also electrons, which is illuminating if you happen to know what electrons are, but not otherwise. For the benefit of those who know what light is but are a bit rusty on electrons, I will say that they are quite small electrically charged particles which are more numerous perhaps than anything else in the universe. They flow through the lamp filament and keep it hot, and some of them come popping out through the surface. They do not get far, however, not those which come out of the filament of an incandescent lamp. They are caught in the electric field inside the bulb, whisked about over curved paths and sent back into the filament. They do not affect the lamp one way or the other. It would look just the same if they did not come out at all. In a radio tube things are different. It is the electrons that count and not the light. It is arranged so that the electrons, instead of going back into the filament, flow from the filament across to a metal plate and then out of the tube through a wire. Just how this makes it possible for you to hear what I am saying is rather a long story with which we are not now concerned. The point is that hot filaments send out two things, light and electrons. In the incandescent lamp we make use of the light; in the radio tube we make use of the electrons.

And now we ask this question. We have seen how it is that an image of the filament can be formed with light—can the same thing be done with electrons? Can all the electrons which come from a single point on the filament—or a lot of them be brought together at another point, and can this be done for all points so that an image of the filament is formed in electrons as in light?

Well, it does not look easy. In the first place, the electrons do not come out through the glass bulb, so if we want to form such an image we will have to form it inside the bulb. Even so, how are we going to see it, suppose we do succeed in forming it? We can not be inside the bulb ourselves and even if we could electrons can not be seen the way we see light with our eyes. When we form an image of the lamp filament on the wall, the light is scattered by the paper—some of it enters our eyes and so we see it. Well, this, as it happens, is the least of our difficulties. There are a lot of different substances—zinc sulfide, for one—which when electrons strike them, shine out. They shine out only where they are struck, so that if we had our electron image formed we could see it by having it on one of these fluorescent screens. It is a special kind of wall paper, so to speak, suitable for seeing

electron images. Well, it is something to know we could see it if we had it. All we have to do now is to figure out how to produce it.

One way of not doing is to use a magnifying glass, because, of course, electrons do not go through glass. They do not go through anything really—not to go in one side and come out the other—not the ones we can work with conveniently in a bulb.

But there are more ways than one of killing a cat. Why send the electrons through a solid material at all, especially as it can not be done. The reason for sending the light through the lens was to deflect it. The deflection was the important thing—not the sending through. Even with light the sending through is not essential; the direction of a light beam can be changed by reflection and light images can be formed by properly shaped mirrors. But here again the method can not be used with electrons; there is no such thing as an electron mirror.

We just forget about glass lenses and curved mirrors and think of the ways in which beams of electrons can be deflected. There is no difficulty in deflecting electrons. It is more difficult not to deflect them. They are deflected in magnetic fields and in electric fields. Let us take an ordinary radio tube and make a small hole in one of the plates that enclose the filament. If we apply a positive potential to the plate—that is, if we connect the positive end of a battery of dry cells to the plates and the negative to the filament—then the electrons which come out of the hot filament will be drawn across to the plates. They move like falling bodies; their speed is continually increasing from the time they leave the filament until they reach the plate. Some of them will pass through the small hole and continue on as a beam. While we are about it, we will suppose that we have joined a long tube to the radio bulb opposite the small hole in the plate and that we have set up one of those fluorescent screens at the end of it which shines out where electrons strike it. The beam strikes the screen and a spot shines out. If we bring up a magnet to the side of the long tube, the spot moves across the screen—the beam is deflected by the field of the magnet. If we try this with a beam of light, nothing happens.

We now place in the tube two metal plates so that the beam passes between them and connect the two plates to the ends of another battery of dry cells. When the connection is made the spot of light on the screen jumps to a new position. The beam has been deflected toward one of the plates and away from the other. We reverse the connections and the beam is deflected in the opposite direction. A beam of electrons is deflected by an electric field. Try this on a beam of light and again nothing happens.

Well, you see we have two ways of altering the direction of a beam of light—by reflection and by refraction—and two ways of altering the direction of a beam of electrons by a magnetic field and by an electric field. In the optics of light the problem is to so shape our reflectors and our refractors as to cause the light radiating from a luminous point—or a part of it—to come together again at some other point—to be brought to a focus. The answer to the problem is curved mirrors and glass lenses.

In the optics of electrons the problem is to so shape our magnetic fields and electric fields that the electrons emitted from a point will likewise be brought to a point focus. We have been working on this problem of shaping fields into lenses at the Bell Telephone Laboratories now for several years; Mr. Zworykin at the R. C. A. Laboratory in Camden has been working on it; a lot of people in Germany have been working on it, and we have all had quite a lot of success. We all produce images of hot surfaces in the electrons which they emit and we all produce electron images of wire gauzes and of holes punched in metal plates.

This is like producing an image of a lantern slide on a screen—only these images are produced in electrons instead of light. How is it done? Well, in the first place, the electrons must always be speeded up by an electric field as happens when they pass from filament to plate in a radio tube. Then those which started from a given point on the emitting surface must be deflected by different amounts according to the different paths they may be on so that their paths will all cross at a point on the fluorescent screen. One way of accomplishing this is to pass them through a small circular coil of wire carrying an electric current—there is a magnetic field in and about such a coil and it happens that its shape—its distribution—is such that it behaves with respect to electrons as a glass lens does with respect to light. It brings the electrons which pass through it to a focus. There is the same sort of correspondence between emitting points and foci as in the light optical case—so that the assemblage of foci forms an image of the emitting surface.

Another way of doing the same thing is to pass the electrons through a hole in an electrically charged plate—the field about such a hole has just the right shape or distribution to serve as a lens. Magnetic lenses are always positive; that is, they are always like convex glass lenses—they always try to bring electrons toward a focus somewhere beyond. Electric lenses are different—they are positive or negative, depending on the potential or voltage of the plate containing the hole relative to other parts of the system. The hole we imagined cut in the plate of the radio tube would be a negative lens; it would be like a concave glass lens—it would fan out slightly the electrons passing through it so that they would be proceeding from a focus back of the plate, not toward one in front of it. To produce an image on the screen we would have to use at least one more plate containing a hole. By passing the electrons through holes in two plates and having the plates at the right voltages the trick can be turned—an image can be formed on the screen.

But why bother? Why go to all the trouble of building up these systems in vacuums to produce images in electrons when perfectly good light images can be produced so much more easily? Well, there are a number of reasons. I will mention one of them only. The highest magnifying power worked with microscopes is about 3,500. This is not because microscopes of higher magnifying power can not be made. We could just put one microscope above another if we liked and have a magnifying power of 3,500 times 3,500. Why isn't this done? Well, it is a matter of resolution. The light from a point in the object does not appear as a point in the field of the microscope—it appears as a spot, a very small spot, but nevertheless a spot. So that two points in the object, if they are very close together, will produce two spots which overlap and so appear to the observer as one spot. The points in the object are not resolved, as we say, in the field of the microscope. And if we added a second microscope to the first, they would not be any better resolved in the field of the second—they would not be as well resolved in fact. Now the size of these spots, and so the resolving power of the microscope, are determined in part by the wave-length of the light—the greater the wave-length the larger the spot and the lower the resolving power. This is why some microscopes are made to operate with ultra-violet light—the wave-length is less and the resolving power higher. Now electrons, strangely enough, have wave-lengths like light—only they are very much less—of the order of one one-thousandth that of ultra-violet light. The situation is then that the ultimate limit of resolving power for an electron microscope is about a thousand times higher than for a light microscope. We are a long way from attaining this limit, but we are on our way.

THE LIVING CELL

By Dr. ROBERT CHAMBERS
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THE invention of the compound microscope in the seventeenth century led to the discovery that all living organisms, both plant and animal, from the largest to the smallest, are composed of minute bodies called cells. These cells are such highly organized and self-sufficient units that millions of organisms consist of just one cell, for instance, all bacteria.

There are two good reasons why we are interested in living cells; one is our natural curiosity regarding these minute structures which embody the mystery of life and, second, the realization that investigations concerning cells bring us to the very root of the problem as to how the organs of our bodies function. It is the knowledge of this upon which medical science depends.

Cells have been a favorite object of study for a long time, but only within comparatively recent years has it been possible to subject them to experimental analysis. One of the difficulties is their small size. If we were to take average sized cells and spread them over an area of 1 square inch we would need 400 to 500 million cells to cover the space. Another difficulty is getting at them without the risk of injuring them. The great majority of the cells are bound together firmly to constitute the organs of our bodies. Others, which are among the smallest of cells, lie in the blood and body fluids where they are free to move about.

One of the most promising methods devised within the last twenty years for examining living cells depends upon the discovery that tiny fragments cut from living tissues will survive in a drop of blood outside the body. The cells in the fragment spread out and continue to grow and multiply under conditions where they can be clearly observed through a microscope. Another useful method has been made possible by the invention of a mechanical contrivance which enables the experimenter to use exceedingly fine glass needles for manipulating individual cells in the highly magnified field of the microscope. In short, the past fifteen years have been marked by developments which enable us to work on the problem in a much more direct manner than had been possible before.

At present what do we know about the cell? We know a great deal of what it is capable of doing, but we are woefully ignorant of how it does it. This is because our knowledge of its constitution is still in its veriest infancy, and even our speculations regarding it are far from satisfactory.

It has been shown experimentally that the cell is a fluid body, marked off from its surroundings by a well-defined boundary or membrane. If our bodies were composed of nothing more than these cells we would be only flabby lumps of jelly. However, many of the cells deposit about them solid materials which form our bony skeleton and, in plants, the woody parts.

The fluid of the cell is in constant motion, although some parts are denser than others. Such differences in density suggest some kind of an internal organization. Within this fluid we find an oval or round body which is invariably present. It is called the nucleus of the cell.

The membrane which encloses the fluid cell has such surprising properties that some investigators regard it as being that part of the cell which is chiefly responsible for the processes which make life possible. It has the faculty of selecting certain substances to pass into the cell and it rejects others. This membrane is not a permanent fix-

ture but is constantly being broken down and as constantly being repaired. The properties of the membrane are so intriguing that we have to-day a school of so-called membrane physiologists who are experimenting in the laboratory with all sorts of membranes and films in the search of a material which will, in some measure, duplicate the properties of the living cell membrane. On the basis of this idea one of the prime functions of the materials within the cell seems to be to keep its membrane intact and in the proper working order.

The condition of this membrane may be illustrated by a crude analogy of a country at war with a thin line of defending troops surrounding it. As long as the line is intact all is well. The personnel of the line is ever changing through individual replacements. Wherever the line breaks reinforcements are rushed from the interior to fill the gap. From the air the interior of the country appears to be in turmoil with troops and lorries traveling in all directions. Evidence of orderly arrangement is most apparent along the thin extended line surrounding the whole. Such is the cell membrane. The life of the cell and indeed life in general is a continual adjustment of internal to external conditions. This means continual work with a constant expendiutre of energy, which is obtained by the cell through nourishment.

How long do cells live? To answer this question we must first realize that all cells can divide into two young daughter cells. This process of cell division is periodic and, in the interval between successive divisions, the two daughter cells grow to the size of the mother cell. In young organisms the cells multiply rapidly from hour to hour. As the organism ages the rate slows down until, when maturity is reached, many cells may carry on for years without appreciable change. However, if an injury should occur the cells can again divide and grow until they have replaced the mutilated tissue. This indicates that the potentialities for continued growth are still present, even in old organisms. Under normal conditions these growth potentialities are held in check. Otherwise, there would be nothing to stop the cells from converting us into continually growing and monstrous giants!

The latent ability of cells to grow without control flares into activity in the dread disease of civilization, cancer. The cells which are affected by this disease lose their subordination to the general economy of the body. They continue to multiply and grow to form the insidious tumors which destroy the body in which they grow.

Cancer differs from the usual human afflictions in being a peculiar state of the living cell. In other diseases our resistance is lowered because our cells weaken and we succumb because our cells die. In cancer, on the other hand, the involved cells are healthy and vigorous, but they are so altered as to have lost their original functions. They persist and grow as living cells but with relationships which are chaotic and vicious.

It is an interesting fact that several of the activities characteristic of the living cell have been successfully imitated with lifeless chemical compounds. This is nothing new. For many years investigators have prepared mixtures of various substances which are amazingly lifelike. They simulate cells in the way they move, subdivide and even grow in size. Some of these mixtures even take up oxygen and give off carbon dioxide, thus breathing superficially in the same way that cells do.

One of the properties of all living cells which is especially evident in cancer cells and which still baffles imitation is the periodic rejuvenation and development of fresh vigor each time the cells divide. The pronounced manifestation of this property in cancer cells suggests that the essential problem of cancer and of cellular physiology are one and the same.

PSYCHOLOGY AND REEMPLOYMENT

By Professor MORRIS S. VITELES

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"WHAT am I going to do about a job?" is a question which gives more concern to each of us—at one or another time of our lives—than any other that is ever asked. At the moment it overshadows all others in the minds of 7 or 8 millions of people who are out of employment. Perhaps to a greater degree than most of us suspect this query is bothering the young people in our high schools and universities, to whom the future presents itself in the form of a large question mark with respect to the important problem of how they are going to earn their living.

The depression has given additional emphasis to this question of the job. It must be remembered, however, that it is present even during so-called prosperous or rich years. It always presents a problem to young people who are for the first time faced with a choice of a career. It is also becoming a question of increasing importance to men in their prime who are thrown out of jobs which they have held for many years because of changes in methods of work or because of variations in demand that make their particular jobs unnecessary. To such men particularly the fear of continued unemployment is an ever-present specter. And, it is important to note, few experiences can be more disturbing to mental health than the haunting fear of losing a job under which so many employed workers are laboring to-day, or the discouragement, the hopelessness, the sense of futility awakened by the inability of the individual to sell his services in the labor market.

A recent study by Hall,[1] of the Personnel Research Federation, gives evidence of this relationship between unemployment and morale. A group of unemployed and a group of employed engineers were compared with regard to occupational morale, attitudes toward employers as a class, etc. Seventy-five per cent. of the unemployed men had poorer morale than the average employed men, and 68 per cent. were more antagonistic toward employers as a class.

The morale of destitute men who had been given "work relief" or "made work" was found to be definitely better than the morale of men who, although similarly destitute, had not received such help. The morale of employed men who anticipated losing their jobs almost any time was as low as that of unemployed men who were in no particular need. In general, the results support the opinion that the grave consequences of unemployment reach beyond material discomfort, beyond the disintegration of skill and health, to undermine a man's attitudes toward his fellows and toward political and social institutions.

According to one estimate, 10,000,000 men who have been employed on white-collar jobs will be forced, during the next 10 years, into manual jobs.[2] Another 15,000,000 manual workers will find it necessary to transfer to jobs requiring skills other than those to which they have been trained. Men thrown out of work by technological changes and for other reasons over which they have no control must be quickly fitted into new forms of work or into already existing occupations where jobs are made available by a decrease in the number of work-hours or through other measures.

[1] O. M. Hall, "Attitudes of Unemployed and Employed Engineers," *Pers. Jour.*, 12: 222–28, 1933.

[2] W. B. Pitkin, "More Power to You," p. 13, Simon and Schuster, New York, 1933.

In the case of these men there is no time to be wasted in trying out one or another job until by chance each finds that for which he is adapted. The rapid adjustment and effective use of this man-power require an exact analysis, by appropriate psychological techniques, of qualifications for work. Only in this way can there be sound and rapid reeducation and placement of each in accordance with the new needs of industry and with the specific qualifications of each worker involved. This means also that traditional notions of vocational fitness must give way to the use of psychological methods in measuring human capacities, temperamental traits, interests and skills that underlie job success. The findings and work of the Stabilization Research Institute of the University of Minnesota, of the Adult Vocational Guidance Clinic conducted by the speaker and of the Vocational Adjustment Service of New York point to the possibilities in this direction. The proposal for testing centers in public employment offices may well mark the end, in the United States, of the attitude that natural selection will ultimately place each individual in his proper economic niche, and the opening of an era of classification and placement on the basis of an exact knowledge of each individual's fitness for work.[3]

The analysis of individual ability, emotional characteristics and interests is only the first step in a scientific program for putting displaced labor into new fields of employment. This must be supplemented by psychologically sound training programs for teaching men the new jobs for which they are qualified.

Industry and vocational schools can very well cooperate to their mutual advantage in the formulation and administration of such programs. Industry, for example, can facilitate transfer within the organization by training its experienced workers—particularly the older ones—in the principles and practises of the jobs to which each can be most easily transferred in case of replacement of his job by machines, of changes in company practises or of temporary economic depression.

The application of this policy may mean, for example, that meter readers in an electric and gas utility will be trained not only in the approved practises of meter reading, but will also receive detailed instruction in the work of the bill collector, the job to which meter reading is related most closely on the organization chart. Employees in traditional coke gas-making plants will become acquainted with the reformed oil process, in preparation for the day when a shift in operating practise may be found necessary, etc. That this is a practicable program has been demonstrated in the work of a number of progressive organizations, such as the Philadelphia Electric Company, which have formulated such training plans as an aid in transferring to available jobs employees who would otherwise be dropped from the payroll.[4]

The vocational school also has a responsibility in this connection. Many of them are still training men for trades which have either disappeared or been completely transformed in the last 10 years. It is apparent that the entire program of vocational education in the schools is in need of reorganization, so that training may cover the exact processes now employed and trades or jobs in the process of development. There is also reason to believe that the vocational schools can make a most important contribution in increasing the general skill and dexterity of those whom they train.

Wherever possible, it is necessary for vocational schools to conduct training so

[3] D. G. Paterson, in J. G. Darley, D. G. Paterson, I. E. Peterson, "Occupational Testing and the Public Employment Office," p. 4, *Employment Stabilization Research Institute Bulletin No. 19*, University of Minnesota, 1933.

[4] M. S. Viteles, "Adjustment in Industry through Training," *Pers. Jour.*, 11: 295–306, 1933.

as to create in the individual a set of fundamental skills that can be used in many jobs, thereby providing for quick adaptation to rapidly changing forms of work. How to develop such adaptability is a psychological problem. The cooperation of the psychologist is needed in formulating methods which will be adequate from the view-point of underlying psycho-physiological processes as well as from the view-point of the working situation. In formulating these techniques certain fundamental questions will have to be answered—such questions as:

Is there a small number of basic capacities underlying skill which can be developed in order to create in the individual a set of fundamental skills that can be used in many jobs, thereby providing for rapid adaptation to rapidly changing forms of work?

Is there a transfer of skill? How can it be used in promoting a better adaptation to work?

Is it possible to make, early in the life of the individual, an analysis of specific abilities and other traits as a basis of outlining a training program best adapted to his needs, to avoid placement in an occupation in which he can attain only the proficiency level of the "marginal worker"?

These and similar problems are being investigated in the psychological laboratory to-day. The answer given to them will to some extent determine the measures to be taken by society in adjusting men to the rapidly changing needs of industry or perhaps, in certain instances, of controlling these changes better to meet the fundamental needs of men.

As Thorndike, of Columbia University, has pointed out, "a steady, industrious, reliable worker has qualities of body and mind and morale which are too important to be wasted because some industrial change has destroyed the value of the special work which he has hitherto performed."[5] Provision for his transfer to suitable and available work must be made. This calls for an extended public program of individual analysis, retraining and replacement, as a focal point for individuals who need guideposts to economic stability and occupational adjustment. The past few years have shown the bewildering lack of such guideposts. Individuals need to be directed to economic stability through occupational analysis and individual planning. The fulfilment of this need calls for the development of a new type of social institution—the Adult Occupational Adjustment and Employment Service. The progress that has already been made in the establishment of such centers and in the development of sound psychological techniques for their use represents a distinct advance in the direction of a healthier occupational system.[6]

[5] E. L. Thorndike, "Adult Learning," p. 180, Macmillan Company, New York, 1928.

[6] J. G. Darley, D. G. Paterson and I. E. Peterson, *op. cit.*, p. 28.

MIRROR MAKING BY THE EVAPORATION PROCESS

By ROBLEY C. WILLIAMS
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RECENTLY a laboratory technique has been developed for coating glass surfaces with metals, which bids fair to displace the former processes by which silver was chemically precipitated upon glass. The deposition of the metal is done by evaporating it in a vacuum chamber and condensing the metal vapors upon the glass to be coated, which is nearby in the chamber. The process accordingly has come to be called the "evaporation process." Mirrors made in this way are generally front-surface mirrors and are of great value to the scientist for the properties of hardness, untarnishability and reflectivity.

The uses and possibilities of this process are manifold. Mirrors for use in work where excellence and uniformity of the metal surface is demanded, and where unusual reflecting properties are advantageous, are best made by evaporation. Glass diffraction gratings, with thirty thousand rulings to the inch, have been coated with metal in this fashion, and so thin is the film that the rulings have not been noticeably filled in, while the brilliance of the spectrum obtained from the grating has been increased many-fold. Quartz fibers for electrometer suspensions are made conducting by evaporating upon them a layer of gold. This was formerly done more slowly by sputtering. Films can be made of varying thicknesses and yet thin enough to transmit some light, and hence can be used as light filters. Cellophane has been coated with aluminum and then used as a window on an x-ray tube, the aluminum serving to filter out the soft x-rays.

To astronomers in particular the process is attractive. Until now all glass astronomical mirrors have been covered by chemically deposited silver, which limits the range of wave-lengths that can be investigated in stellar spectra. Of course, the opacity of the earth's atmosphere prevents photographing wave-lengths shorter than 3000 Ångstrom units, but silver becomes relatively useless at 3500 Ångstrom units. Consequently this ultra-violet region from 3000 to 3500 Ångstrom units has been investigated for only the brightest stars. The advent of evaporated aluminum mirrors allows the astronomer to examine stellar spectra of wave-length as short as the atmosphere transmits, and furnishes him further with a mirror surface which will not tarnish and which is considerably harder than the silver-on-glass surfaces.

The process is not new, and several have contributed to its present state of development. Its forerunner was the cathodic "sputtering" technique by which a metal is bombarded in a partial vacuum by high-velocity ions of a suitable gas, and pieces of the metal are knocked off. The glass to be coated is in the same chamber, and the metallic particles which have been "sputtered" off adhere to the glass. The deposition goes on very slowly and is limited practically to small surfaces. Metals which form oxide coats, like aluminum, can not be readily deposited by cathodic sputtering.

As long ago as 1894 Edison realized the possibility of thermally evaporating metals in a high vacuum, and he obtained a patent upon this idea in that year. He experimented with three methods of deposition: the use of an arc the electrodes of which were of the metal to be deposited; the heating of a wire of the desired metal almost to the melting point with consequent slow sublimation; the use of carbon vessels as heating ele-

THE FIRST MULTIPLE-FILAMENT APPARATUS USED AT CORNELL TO COAT LARGE MIRRORS BY EVAPORATION

ments upon which the metal was to be placed. Evidently the technique was none too successful, for little was done with it at that time.

Subsequent to Edison's patent, various patents were granted upon variations of the principal idea, but no significant advance was made until about 1929. Some years prior to this a valuable spectroscopic instrument had been perfected, the Fabry-Perot interferometer, which has as its principal parts two plane, half-silvered, glass plates. Although opaque silvering is done very successfully by the chemical process, it is almost impossible to obtain satisfactory half-transparent films. Consequently, experimentalists at the Physikalische Technische Reichsanstalt in Berlin investigated the evaporation technique for use with these interferometer mirrors. They were aided by the developments that had been made in producing tungsten wire of all sizes and were able to use this metal as the heating element instead of the carbon tried by Edison. They were very successful in employing the method for half-silvering and obtained films of silver that were uniform, unpitted and capable of reflecting 95 per cent. of the incident light. Furthermore, they produced films of aluminum alloys that gave excellent reflectivity in the ultra-violet region of the spectrum.

About a year later work on the process was begun in this country at the California Institute of Technology and at Cornell University. These institutions developed vacuum chambers which allowed experimentation with many shapes and sizes of glass and with the use of a plurality of heating elements. In the summer of 1931 the Cornell investigators began to consider the possibility of using the process for large astronomical mirrors. They hoped to find a metallic surface to take the place

of chemically deposited silver which tarnishes, reflects very poorly in the ultraviolet and is quite soft. The following summer they coated the Lowell Observatory 15-inch mirror with chromium, and used this in an attempt to photograph the ultra-violet spectrum of the corona during the 1932 total solar eclipse. Chromium was chosen for its extreme permanence and its excellent relative ultra-violet reflectivity. This mirror was the first astronomical mirror to be coated by the evaporation process. The work has been extended so that at the present time there are numerous institutions working on the problem. The 36-inch astronomical mirror of the Lick Observatory, which has recently been covered with aluminum in a 40-inch vacuum chamber at the California Institute of Technology, is the larges' mirror yet coated.

As previously stated, the essential parts of the apparatus are a vacuum pumping system, a vacuum-chamber to contain the glass surface, and the heating elements, and supports for the electrically-heated tungsten wires upon which is placed the metal to be evaporated. For the first, a large oil fore-pump and a mercury or oil-diffusion pump is used. Since a pressure of about one ten-millionth of atmospheric pressure is needed, the pumps must be fast and efficient. The vacuum-chamber is generally a glass or metal dome waxed down to a metal bed-plate with low vapor-pressure wax. In the bed-plate are mounted insulated lead-wires which connect to the tungsten wires to be heated. The tungsten wire is generally wound into a straight helix or a conical helix, and the metal to be evaporated placed within. The object to be coated is placed in the chamber and is often suspended inverted over the tungsten filaments at a distance of a few inches. The glass surface must be cleaned with utmost care, and a method of cleaning by electron bombardment has recently been developed at the California Institute. After the glass and filaments have been placed in position and the desired vacuum obtained, the actual evaporation of the metal takes only a few minutes. The mirrors thus made require no further treatment and, in fact, an attempt at polishing may result in marring them. The films are only about one one-hundred-thousandth of an inch thick, and hence fit the contour of the glass surface exactly.

The properties of these metallic films for use as mirrors vary widely. At the present writing about twenty-five different elements have been evaporated. Included are common elements like silver, gold, copper and aluminum, and rarer ones like germanium, selenium, palladium and beryllium. Those elements with extremely high melting points or which attack the tungsten filament upon being heated are extremely hard to evaporate. The former problem is being solved at the Massachusetts Institute of Technology, by bombardment of the metal to be evaporated by high-velocity electrons. The ideal metallic mirror coating, of course, is one that is permanent and hard, and which possesses high reflectivity throughout the spectrum. No element yet evaporated fully satisfies all these requirements. Chromium is so hard and resistant that it can be removed from glass only with abrasives, yet its reflectivity is below that of some other metals. Although some other metals have a higher reflectivity than aluminum in certain regions of the spectrum, aluminum has an average reflectivity for the entire spectrum range higher than that of any other metal. Furthermore, due to the formation of a thin, transparent oxide coating over the metal surface, aluminum films do not tarnish, but they are too soft to be ideal. Aluminum is the best all-around mirror surface yet developed, however. Alloys have been worked with, and there are possibilities that eventually the ideal mirror will be produced from them.

THE PROGRESS OF SCIENCE

THE BERKELEY MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE ninety-fourth meeting of the association was held at Berkeley in June under the joint auspices of the University of California and the Pacific Division of the association. It attracted a large attendance; 1,164 persons registered for the meeting and several hundred others who failed to do so participated in some of its numerous sessions. Nine tenths of the registration came from the region included in the Pacific Division, the remaining one tenth from more distant localities, a number from foreign countries. This meeting was the second national meeting in the San Francisco Bay Region, a previous summer meeting having been held in 1915 during the Panama-Pacific Exposition.

Details as to arrangements for the meeting were left largely in the hands of the local committee. Besides its customary duties it was called upon to assemble the program material and to prepare it for printing and to handle publicity. By an arrangement with Mr. Austin H. Clark, the preparation of news releases and other details in connection with publicity were delegated to Mr. George A. Pettitt, of the University News Service, who organized and conducted a press bureau where abstracts and manuscripts, as well as the necessary physical facilities, were available to news correspondents. This news service was widely used and instrumental in securing extensive publicity for the meeting not only in the local but also in the national press. Authority for preparing programs was largely delegated to secretaries *pro tem*, appointed for the meeting by the permanent secretary on nomination of the local committee, and most of the associated societies delegated the responsibility for assembling their programs to local representatives. This innovation proved very successful since it promoted a close contact between the local committee and the various persons responsible for the preparation of programs. It also facilitated assignment of rooms and provision of physical facilities, since the local representatives were familiar with conditions at Berkeley. This arrangement was no doubt largely responsible for the smoothness with which the meeting was carried out.

The meeting occupied an entire week, Monday to Saturday, inclusive, from June 18 to 23, 1934. The first plan was to devote morning periods to scientific sessions; afternoons to informal conferences, excursions, field trips, social affairs, etc., and evenings to general sessions featuring speakers of national prominence. When the program material was received, however, it so far exceeded expectations that most of the sections and societies were forced to schedule additional sessions, with the result that afternoon periods were also largely given over to scientific sessions.

Five evening sessions were arranged by the permanent secretary, Dr. Henry B. Ward, and they were well attended, not only by participants in the meeting but also by the general public. On successive evenings Dr. Joel H. Hildebrand delivered the retiring address of the president of the Pacific Division on "The Liquid State"; Dr. L. Dudley Stamp delivered the third Hector Maiben lecture on "Planning the Land for the Future"; Dr. J. C. Merriam spoke on "Responsibility of Science with Relation to Government Problems"; Dr. E. B. Wilson discussed the topic, "Are There

AIRPLANE VIEW OF THE BERKELEY CAMPUS OF THE UNIVERSITY OF CALIFORNIA

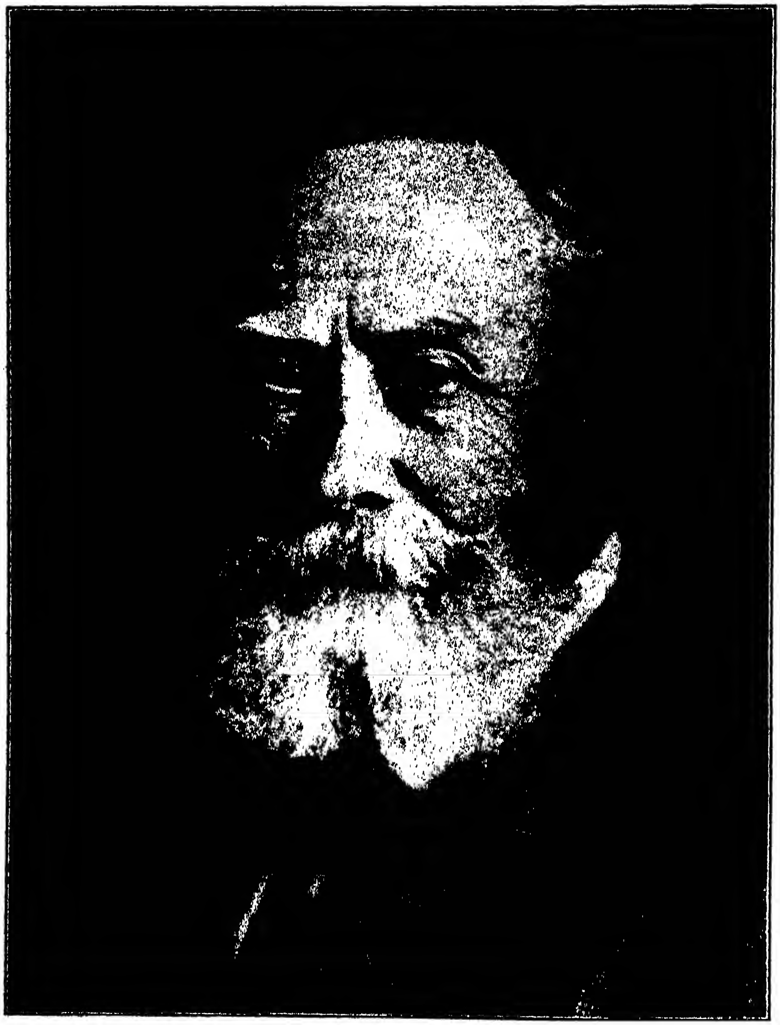
Periods in American Business Activity?''; and Dr. Karl T. Compton delivered an address on ''Science and Prosperity.'' The assignment of the Hector Maiben lecture to the summer meeting was particularly appreciated; and it is hoped will lead to the development of other special features for forthcoming summer meetings.

At business sessions of the Pacific Division, Dr. Bailey Willis, emeritus professor of geology in Stanford University, was elected president of the division, succeeding Dr. Joel H. Hildebrand, and Dr. W. V. Houston, professor of physics in the California Institute of Technology, was elected to the executive committee in succession to Dr. S. J. Barnett, professor of physics in the University of California at Los Angeles.

Besides the general sessions a number of features arranged by sections and societies were of more than special interest. These included addresses by E. A. Sperry on ''The Automatic Pilot''; by Göte Turesson on ''Ecotype Constitution and Geographic Distribution''; by Professor H. C. Thompson on ''Relation of Temperatures and Length of Day to Reproduction in Plants''; and by Robley D. Evans on ''Radioactivity and the Age of Meteorites.'' Dr. C. A. Kofoid presented the new edition of the Canti film with slides, and original films on ''American Mammalian Trypanosomiasis'' by Dr. C. A. Kofoid and on ''Development of the Amphibian Egg'' by Professor J. A. Long were shown at another public session. On Friday, through the courtesy of the Commonwealth Club of California, national officers, speakers and presiding officers at the general sessions of the association were present as guests of the club at its regular luncheon meeting in the Palace Hotel in San Francisco, at which Dr. R. A. Millikan spoke on ''Science and National Welfare.''

Social features of general interest included a reception held on Monday evening, following the opening general session, at which music, dancing and refreshments were enjoyed by those in attendance; and general teas on Tuesday afternoon at the Women's Faculty Club and on Wednesday afternoon at the International House, at which a program of Japanese music, dancing and flower arrangement was featured and Japanese ladies in native costume served refreshments. Besides the general social events, numerous luncheons and dinners were arranged by special groups. Some of these dinners were followed by programs of various kinds; as, for example, the biologists' dinner, at which Dr. A. F. Blakeslee gave a demonstration of differences in perception as to taste and smell and spoke briefly on the inheritance of such variations; the engineers' dinner, at which the Daniel Guggenheim Medal was presented to William Edward Boeing, and Chester Harvey Rowell spoke on ''Regimenting the Professions, Engineers Included''; the physicists' dinner, at which Professor R. W. Wood spoke on ''The Physicist as a Detective''; and the psychologists' dinner, at which Dr. E. R. Guthrie delivered the presidential address on ''Skill and Associative Learning.'' The numerous luncheons, dinners and other social affairs unquestionably contributed largely to the informal and friendly atmosphere which was characteristic of the meeting.

Special affairs arranged for visiting ladies included a garden tour, a tour to Mills College, a personally conducted trip to Chinatown and a tea at the College Women's Clubs. Besides these affairs visiting ladies participated in the general social events and in the luncheons and dinners arranged by special groups. Excursions were also arranged to Davis to visit the branch of the College of Agriculture; to Mt. Hamilton to inspect the Lick Observatory; to Stanford University, where a special program was arranged and a booklet descriptive of the university was distributed; and to



PORTRAIT OF BAILEY WILLIS
EMERITUS PROFESSOR OF GEOLOGY IN STANFORD UNIVERSITY, NEWLY ELECTED PRESIDENT OF THE PACIFIC DIVISION, A. A. A. S.

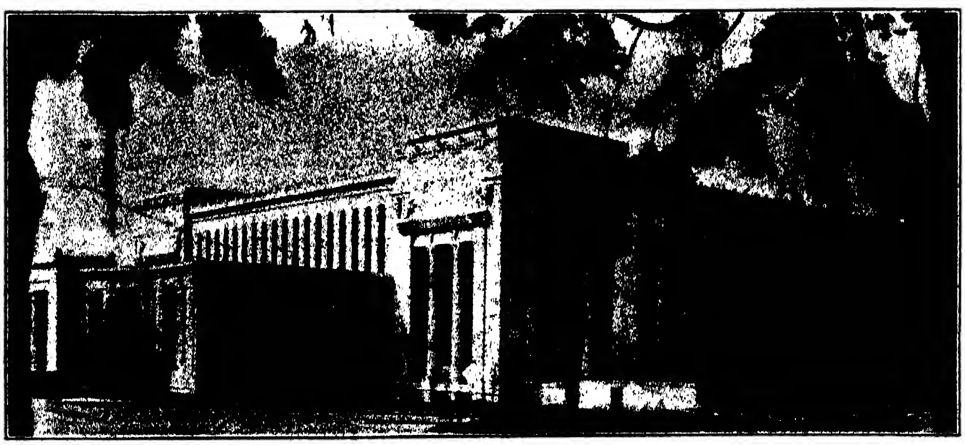
the California Academy of Sciences, which served a complimentary buffet luncheon to about 175 persons in their Simson African Hall. Visitors were given an opportunity to inspect the departments and exhibits of the academy and in the afternoon they were given a free automobile bus tour of San Francisco through the courtesy of the San Francisco Chamber of Commerce.

On Tuesday afternoon many of the university departments held open house, at which an attempt was made by means of informal exhibits and demonstrations to acquaint visitors with research activities of the university. A special exhibit of books of epochal significance in the history of science, selected under the supervision of Professors H. M. Evans and J. W. Thompson, attracted a great deal of attention. A booklet containing annotations on the items included in the exhibit was prepared and printed for the meeting. The exhibit included an

STEPHENS UNION BUILDING
HEADQUARTERS OF THE ASSOCIATION FOR THE BERKELEY MEETING. THE REGISTRATION OFFICE AND QUARTERS FOR THE NATIONAL OFFICERS WERE LOCATED HERE, ALSO SPACIOUS LOUNGING ROOMS WHICH SERVED AS A CENTRAL GATHERING PLACE DURING THE MEETING.

extensive collection of portraits of scientific worthies, mostly in the form of engraving, from the private collection of Professor H. M. Evans and portions of the Hearst Medical Papyrus. The National Park Service, through the courtesy of Ansel F. Hall, placed a large collection of relief models of national parks on exhibit. Besides the specially prepared exhibits, a number of the university collections were thrown open to inspection throughout the week.

Space forbids any detailed account of the special programs of sections and associated societies. Of the fifteen active sections of the association, fourteen were represented by extensive programs. No attempt was made to arrange a program in geology and geography, owing to the fact that associated societies in this field



LIFE SCIENCES BUILDING
IN WHICH MOST OF THE SESSIONS IN THE BIOLOGICAL SCIENCES AND IN RELATED FIELDS WERE HELD.

PORTRAIT OF JOEL H. HILDEBRAND
PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF CALIFORNIA, RETIRING PRESIDENT OF THE PACIFIC DIVISION, A. A. A. S.

on the Pacific Coast had held a joint meeting in Berkeley in April, which was well attended and brought forth a very extensive program. Nevertheless, this field was represented by a joint luncheon conference of the Committee on Oceanography of the Pacific and the Western Society of Naturalists. Eight hundred and fifty papers are listed in the special programs and 36 associated societies and other organizations cooperated with the sections in the meeting. Copies of the complete program may be obtained from the permanent secretary.

Several sections which frequently are not well represented at association meetings presented extensive programs at this meeting. The Social and Economic Sciences, in cooperation with the Econometric Society, the American Statisti-

cal Association and the Western Farm Economic Association, presented a program consisting of no less than twelve sessions and in addition joined with Agriculture in a three-day program on "Land-Use Planning." Agriculture was also represented by a specially arranged symposium on "Weed Control," in which fundamental features of the problem were emphasized, and by sessions of the Western Society of Soil Science, which devoted one day to a symposium on "Phosphate," and of the American Society of Agronomy (Western Branch). The Historical and Philological Sciences and the Medical Sciences were represented by a unique symposium on the Hearst Medical Papyrus, portions of which were included in the exhibit of old books. The program of the Medical Sciences opened with a memorial service in honor of Dr. William H. Welch, at which J. McKeen Cattell presided and Ray Lyman Wilbur spoke on the life and work of Dr. Welch. The remaining portion of the program in the Medical Sciences was devoted to endocrinology, nutrition, hygiene and epidemiology and parasitology. Sessions were also held by the Society for Experimental Biology and Medicine (Pacific Coast Branch) and the California State Veterinary Medical Association. Engineering was represented by programs of the Aeronautic and Hydraulic Divisions of the American Society of Mechanical Engineers and by joint programs of the Hydrology Section of the American Geophysical Union and the Pacific Coast Section of the American Society of Agricultural Engineers and by a program of the Western Inter-State Snow Conference. Education arranged a program of five sessions devoted to selected topics and joined with Psychology in a symposium, "Can Personality be Measured?" Psychology presented a very extensive program under the auspices of the Western Psychological Association.

Sessions of the other sections were very fully represented, mostly through the medium of associated societies. Their programs consisted not only of contributed papers but also of symposia and special programs on various topics. The physicists held symposia on "Nuclear Structure" and on "Fundamental Physical Constants"; they also joined with the astronomers in a symposium on "Spectroscopy in Astrophysics." The chemists presented invitational programs on selected topics in physical chemistry and in biochemistry. The zoologists held a symposium on the "Protozoan Life Cycle"; the botanists on the "Origin and Development of North Pacific Floras" and on the "Absorption and Accumulation of Mineral Elements by Plant Cells"; the geneticists on "Genes in Relation to Characters"; and the Medical Sciences on a "Survey and Evaluation of the Present Status of Endocrine Investigations." Besides the symposia, most of the special programs noted in the preceding paragraph were made up of invitational papers.

A special feature of the meeting was the large number of joint sessions which were arranged among societies and sections with common interests. While this practise gave rise to some editorial difficulty in arranging the program, it no doubt avoided to some extent conflicts which might otherwise have been troublesome. The programs as a whole were not only extensive but also of high quality and with few exceptions the sessions were extraordinarily well attended, to such an extent that in several instances original room assignments had to be changed at the last moment to accommodate larger audiences. The ninety-fourth meeting of the association was a distinctly enjoyable and profitable event and no doubt contributed largely to an appreciation of the work of the association on the Pacific Coast.

Roy Elwood Clausen

MADAME MARIE SKLODOWSKA CURIE

Hidden now by a row of beech trees Madame Marie Curie's grave lies in a little village cemetery at Sceaux, France. She died on July 4, 1934, after a brief illness. Too busy to be famous, too much in love with her work to consider fame more than a by-product of labor and zeal, she believed with her husband "No matter what it does to one, even if it makes of one a body without a soul, one must go on with one's work." Yet she found time for her two daughters, Irene and Eve, and for her friends, just as in the early days of her marriage she had found time to do her own housework, teach classes and make her discoveries.

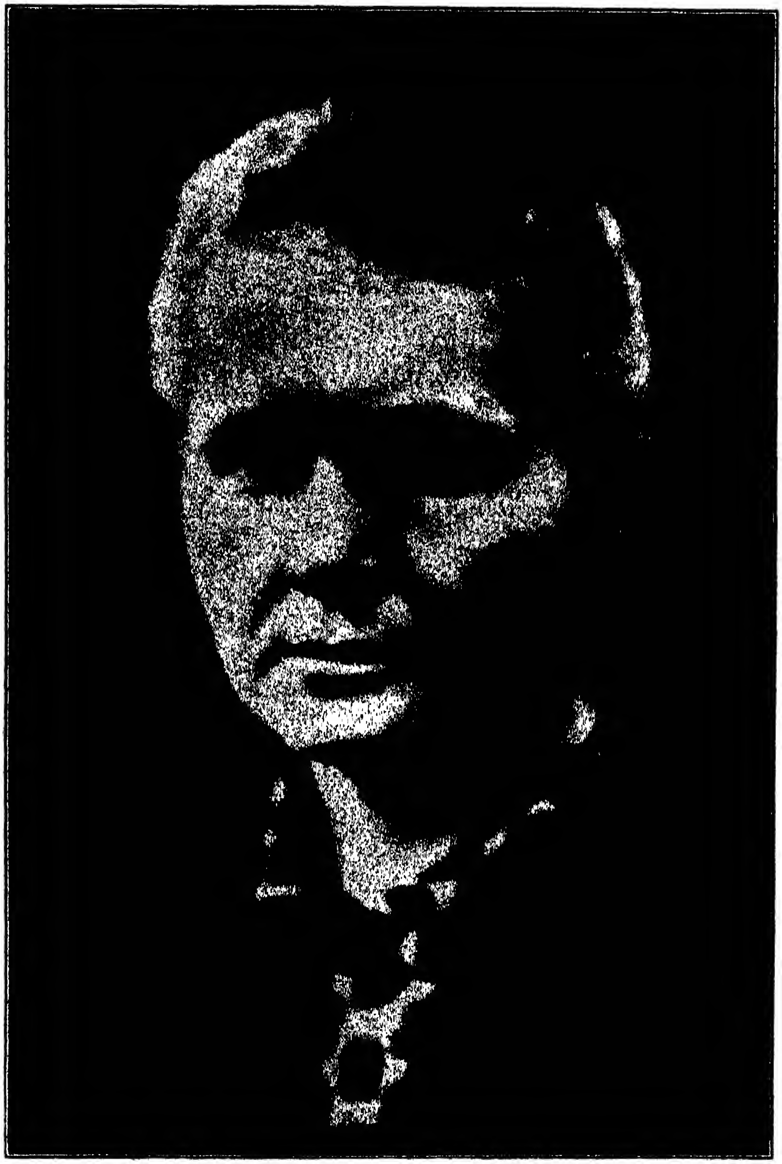
Born in Warsaw, Poland, on November 7, 1867, Marie Sklodowska received her first scientific training and part of her heritage of patience and curiosity from her father, who was a Polish educator. From Warsaw she went first to Cracow, then to Paris to study, taking a degree in science at the university there, and began the long series of experiments which continued for nearly forty years.

When she was twenty-eight she married Pierre Curie, a physicist working on magnetism and crystallography. They had no money but they had pleasant whims, for Mme. Curie is said to have bought a tandem bicycle with her wedding money.

Their common dower was that infinite capacity for taking pains which has been defined as genius. They had also an endowment of zeal or patience or curiosity to forge ahead, even though the laboratory roof leaked rain or snow. They worked in an abandoned shed. "It was only a wooden shack," Mme. Curie said, "with a skylight roof which didn't always keep the rain out." They must have worked late and arduously, for both had much teaching to do in order to make a living. They worked in their overcoats in the winter, to make the money which might have gone for warmth to feed that other fire, "for we had to pay for our scientific research out of our own pockets"—thin pockets for the fabulous pickings they were to yield the world.

The year after the young Curies joined forces, Henri Becquerel, a friend of both, discovered the radioactive properties of uranium, an indirect consequence of the discovery of x-rays made a few months before by Röntgen. Thus the beginning of the study of radioactivity dates from 1896. Separation of the uranium left a residue three to five times as radioactive weight for weight as the uranium. She first separated from the residue a substance far more active than uranium which was named polonium in honor of Mme. Curie's native land. Working together the Curies then separated a second radioactive substance which they named radium. It is a fiercely active substance, for in the pure state radium bromide has an activity about two million times as great as an equal weight of uranium. Mme. Curie found the atomic weight of radium to be 226 and later prepared an international radium standard of about twenty-two milligrams of pure radium chloride preserved in the Bureau International des Poids et Mesures at Sèvres, near Paris. Secondary standards, checked carefully with this primary one, are kept in other places, there being one at the U. S. Bureau of Standards, Washington.

Before Professor Pierre Curie's death in 1906 when he was run over and killed by a dray in Paris streets, the couple were inseparable in the laboratory and at home, and working together did much to elucidate the properties of radium and its transformation products. They were awarded the Davy medal of the Royal Society in 1903, and the Nobel prize for physics was divided the same year between them and Henri Bec-



Henri Manuel

MME. MARIE SKLODOWSKA CURIE, 1867–1934

PROFESSOR OF RADIOACTIVITY AT THE UNIVERSITY OF PARIS. WITH HER HUSBAND, PROFESSOR PIERRE CURIE, SHE DISCOVERED RADIUM AND POLONIUM, AND FOUNDED THE SCIENCE OF RADIOACTIVITY.

querel. Professor Curie was elected to the Academy of Sciences in 1905, just one year before his death.

Mme. Curie succeeded him as professor at the University of Paris, the only woman to hold the post of university professor in France. She was also the only person to receive a second Nobel prize (1911) for isolating radium as a pure metal and for determining its atomic weight.

Theoretically, the importance to science of the discovery and isolation of radium is great because radium has played an extensive part in the growth of knowledge of the internal structure of atoms in general. The discovery of polonium and radium led to the modern analyses of radioactivity in terms of the spontaneous transformation of the radioactive bodies.

The first gift of radium to Mme. Curie from the women of America was made in May, 1921, when she visited this country. The gift was prepared by the women of America when Mme. Curie said she would rather have one gram of radium for her own use than anything in the world. Madame accepted it with the shy graciousness which characterized her dealings with fame, ending her little speech to the President after his presentation of the radium, "I thank your countrywomen in the name of humanity which we all wish so much to make happier," and then impulsively, "I love you all, my American friends, very much."

She had papers drawn making the gram of radium the property of the Curie Institute at the University of Paris, and willed it to the University "on the condition that my daughter, Irene Curie (now Mme. Joliot Curie, the wife of M. Frederic Joliot, a distinguished man of science, who subsequent to his marriage consented to take the family name of his wife) shall have during her life entire liberty to use this gram of radium."

On the occasion of her first visit to this country, Mme. Curie received honorary degrees from Yale University, Smith College and the University of Pennsylvania. When she returned in 1929, the honorary degree of Doctor of Science was conferred on her by St. Lawrence University. On this occasion Mme. Curie dedicated the Hepburn Hall of Chemistry at the university, before which a statue of her had been erected.

After the gram of radium had been presented, a gift of a yearly income of $3500 was also given, since Mme. Curie had been forced all her life to live frugally. But she did not seem to know how to spend money on herself and she used the money to rent a gram of radium for the use of the Warsaw Hospital. On October 30, 1929, she was presented with a second gram of radium in this country in order to release the income given earlier for her own use. President Hoover in making the presentation paid tribute to the fundamental importance of scientific research. Mme. Curie in accepting the gift said, "My work is very much my life, and I have been made happy by your generous support of it. . . . I feel deeply the importance of what has been said by the President of the United States about the value of pure science; this has been the creed of my life. Scientific research has its great beauty and its reward in itself; and so I have found happiness in my work."

To some extent the life of Mme. Curie was shortened by the nature of her work. For years her hands had been very tender, and press reports stated that her death was due to a form of pernicious anemia caused or hastened by exposure to the radioactive substances with which she worked.

E. P. S.

THE HOPI INDIAN STAIRWAY AT WALPI

THE Museum of the American Indian has recently acquired two large paintings of the Hopi Indian stairway to the town of Walpi, Arizona, by Mr. Frederick S. Dellenbaugh, an explorer of the canyons of the Colorado with Major Powell in 1871 and 1872. The stone slab stairway exhibits considerable engineering skill, and is the southern entrance to the town of Walpi, perched in an impregnable position seven hundred feet above the valley. No storming party could enter the town by the stairway without being annihilated with stones thrown from above. There is one northern entrance only a few feet wide leading up between perpendicular cliffs from the summit of the mesa. Years ago a band of hostile Navajos attempted an entrance by this passage and twenty-five of them were thrown over the brink to crash below. The second painting of Walpi from the north shows the narrow passage to the town, with the San Francisco mountains in the distance.

R. W. P.

THE DROUGHT AND ITS EFFECTS ON AGRICULTURAL CROPS

WEATHER reports for July, covering the entire United States, continue to establish the 1934 drought as the worst in American records. The northwest, midwest and southwest portions of the country remained not only unrelieved from what is for much of their area the fifth successive summer of drought, but July tended to intensify their distress, except in scattered local areas.

When the United States as a whole is considered, July was not only outstandingly dry but the hottest month ever known, with the all-time maximum temperature records exceeded in many places, especially in the Mid-Western States. Examination of the rainfall map of the United States, covering the same month, shows a drought by no means as wide-spread as the heat. Numerous localities, scattered throughout the country, had more than average rainfall, but those territories most severely affected by the spring drought were not among them. The Department of Agriculture also reports that the departure of average July temperatures from normal for different sections of the country is quite similar to that which occurred in July, 1901, the previous hottest month on record, though the departures from normal were somewhat larger in most places in 1934 than in 1901.

Rainfall during July could not have saved pasture, hay, and small grains generally, for their critical period had passed. The corn crop may still be saved, for its critical period occurs later, but each week with diminishing optimism the Department of Agriculture gives out successively lower estimates of the expected crop.

The shortage of water has also taken heavy toll among the livestock in the stricken area. Over 2,500,000 head of cattle have been purchased by Federal agencies and shipped to stockyards to be slaughtered and canned before they starved to death from lack of fodder.

Eight hundred thousand persons in the western half of the United States are on the relief rolls of the Emergency Relief Administration, and the total damage to growing crops and livestock has been estimated by Emergency Relief Administrator Harry Hopkins at five billion dollars, with twenty-seven million people and sixty per cent. of the country's area affected. Although serious problems of distribution will arise, the Agricultural Adjustment Administration is convinced that the nation does not face any danger of food shortage despite the drought. Secretary Wallace of the Department of Agriculture estimates that general living costs might be expected to increase from 6 to 7 per cent. as a result of the drought, food costs taken separately increasing from 15 to 20 per cent. A food and feed survey is going forward to determine just what the food supply is and orders have been given to the Department of Agriculture crop experts to send in immediately data on the food, feed and seed supply available on farms, country elevators and other storage facilities.

At the date of writing, August 15, heavy rains had come to break the drought in the most severely hit of the Middle Western regions, and although it came too late to help major crops, it may enable a fair amount of the corn crop to be salvaged, and it brought some relief from the acute water shortage.

M. L. G.

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BIOLOGY AND SOCIETY[1]

ANIMAL SOCIETIES

By Dr. WILLIAM MORTON WHEELER

PROFESSOR OF ENTOMOLOGY, HARVARD UNIVERSITY

Τά τε ἐλάχιστα τῶν ζώων τὰς συνελεύσεις αὐτῶν ἐν εἰρήνῃ καὶ ὁμονοίᾳ ποιοῦνται. (And the least of the animals enter into their associations in peace and concord.)—*Clement, Epistle to the Corinthians*, I, 20.

"Nicht einmal die Volksgemeinschaften, in denen überall der Klassenkampf tobt, tragen den Stempel mütterlichen Geistes, der allein aus den vielen Einzelgliedern eine wirkliche Volksfamilie schafft, wie uns die sozialen Insektenstaaten lehren." ("Not even the communities of nations, in which everywhere class-war rages, bear the imprint of the maternal spirit, which alone is able to create a true family of the people out of the many separate members, as we are taught by the social states of the insects.")—*E. Bergmann, Erkenntnisgeist und Muttergeist*, 1933, p. 275.

It is common knowledge that many infrahuman organisms, both plant and animal, live regularly in aggregations, associations or communities more or less like our own societies. The biologists' domain is supposed to cover the entire range of this "togetherness" behavior of whole organisms from Bacteria to Anthropoid apes, while the sociologist reserves for himself the study of human societies. We may be prepared, therefore, to find considerable divergence between the biologist's and the sociologist's points of view. I infer that I am to represent the biologists in this symposium, not because of any competency to synthesize what they have learned in so vast a field, but because of my long interest in a group of animals whose activities have always seemed, even to the most casual observer, to exhibit certain interesting resemblances to the social and political behavior of man. Instead, however, of dwelling on these resemblances, which, though interesting, are superficial and have become rather trite, I propose, after commenting briefly on the position of the study of organismal consociations among the biological sciences and the abundance and variety of these consociations, to consider at greater length some of the more fundamental social differences between the two dominant groups of animals, represented by the social insects on the one hand and the warm-blooded Vertebrates, man included, on the other. Though my argument will compel me to trespass on the preserves of the gentlemen who are to continue the symposium, I trust that my remarks will be received as offered in a spirit less dogmatic than their necessarily brief and abrupt exposition may seem to suggest.

[1] A symposium presented on the occasion of the celebration of the semi-centennial anniversary of the American Society of Naturalists at the fifty-first annual meeting at Harvard University on December 30, 1933.

During the nineteenth century biology and sociology developed in rather intimate symbiosis. Though Comte founded sociology on biology, it is well known that certain important conceptions, such as the struggle for existence, the survival of the fittest and the physiological division of labor, were derived from sociological sources and later extended to the entire world of organisms in the Darwinian theory of evolution. If we may judge from the works of Spencer, Espinas, de Lilienfeld, De Greef, Worms, Waxweiler and others, this theory, after its first clear enunciation, seems to have been more heartily welcomed and embraced by the sociologists than by the biologists. Subsequently, however, owing to the great opportunities for investigation, which had been opened up, in their respective fields, in the latter part of the nineteenth and the beginning of the present century, the biologists and sociologists drifted apart. The biologists specialized increasingly in the classification, morphology, physiology and genetics of the individual organism, while the sociologists seemed to lose much of their interest in biology and proceeded to ally themselves more closely with the psychologists, historians, economists and ethnographers. It was not till the recent development of ecology as an independent formulation of what had long been known as natural history that the study of plant and animal consociations acquired scientific status. This science has now been divided into autecology and synecology, the former concerned with the external adaptations of the individual organism, the latter with the plant and animal consociations. There are reasons, however, for regarding autecology as a department of general physiology and synecology as constituting the proper domain of ecology. At any rate, synecology seems to cover the same field as sociology in its broadest sense, or what might be called general comparative sociology, which would, of course, include not only human societies but also all the various consociations of plants as well as animals. Man will always be a mammal and his basic behavior will always be mammalian behavior. That he also exhibits other and very different activities justifies the recognition of human sociology as a special field, but so many of his so-called "spiritual" idiosyncrasies are now being traced to behavioristic rudiments among the primates that the biologist will look askance at all the attempts of the ideologists to sever, or even to stretch unduly, the bonds between his science and sociology (1).

A very brief survey will suffice to reveal the great extent and variety of consociative behavior in the animal kingdom. Indeed, there is no animal species that does not exhibit some such behavior, even if it fails to outlast the brief mating period or the temporary association of mother and offspring or amount to more than membership in some biocoenotic community. I find it convenient to classify all the animal consociations under seven heads. First, there are the loose and unstable populations known as aggregations, which consist of the same or different species and are very frequent among Protozoa, Invertebrates and cold-blooded Vertebrates. In many of the cases recently studied by Allee and others the individuals are assembled and kept together mainly by their tropistic or sensory responses to very local environmental stimuli, but others, such as the mating congregations of many insects, the migratory swarms of locusts, etc., arise in response to interindividual stimuli or to combinations of these with environmental stimuli. We should place in a second category the very different, compact and mainly nutritive consociations exemplified by the multicellular bodies of all Metazoan animals, the zooidal colonies of many Coelenterates, Bryozoans,

Tunicates, etc., and the series of metameres constituting the bodies of Annelids, Arthropods and Vertebrates, if, as many zoologists believe, these metameres are really serial, abortive zooids. The third category comprises the peculiar "food associations," consisting of individuals of two different species, of which one may be a plant, and exhibiting various kinds and degrees of intimacy as in the cases of predatism, parasitoidism, parasitism, commensalism, domestication, symbiosis, fungus-culture, the associations of mites, ants and beetles with certain peculiarly specialized plants, and the vaguer phenomena of myrmecochory, mimicry, etc. The food associations are so very numerous, diverse and economically important that they have been made the subject of an independent science, parasitology. A fourth category comprises the flocks and herds of the birds and mammals, and include as their most highly developed examples the troops or bands of monkeys and Anthropoid apes. A fifth category would comprise the insect societies, both temporary (subsocial) and permanent. The number and diversity of the latter are very great, since there are fully 10,000 species of social insects, each of which may be said to have its own peculiar pattern of social behavior. To the sixth category I would assign the human societies and to the seventh the biocoenoses, or what the ecologists call "communities," those consociations of animals and plants of various species, attached to particular ecological environments, such as the interdependent faunal and floral elements of a forest, cave, desert, stream, sand dune, etc. These communities are so complex, unstable and difficult of definition that their adequate analysis seems to be impossible with our present biological methods. The totality of existing biocoenoses may be said to constitute one great super-biocoenose, embracing all living organisms, man, of course, included, and equivalent to the biosphere, or thin, more or less discontinuous film of living matter covering the lithosphere and pervading the hygrosphere of our planet.

Some authors have referred all the heterogeneous consociations I have enumerated to a single "cause," variously designated as the "social," "gregarious" or "herd instinct," but this is mere animistic verbalism. That a consociation can have no single "cause," but is determined by a set of conditions, and that each of the many consociations is determined by its own set of conditions would seem to be inferable from the following considerations:

(1) The various consociations, as patterns of group or mass behavior, are obviously so many forms of adaptation, or "adaptates," to use a term invented by the sociologist Tarde. And while we may, perhaps, recognize homologous consociations among taxonomically closely related species, we agree with Ward and Petrucci that at least the more complex and dissimilar types represent independent, polyphyletic and therefore merely analogous, or convergent adaptates. This seems also to be true of many similar consociations, so that no classification of the types or forms of societies can be a "natural" classification, nor coincide at all closely, except within the narrow confines of families or genera, with our morphological or taxonomic classification. I am convinced that during the long phylogenetic history of the Insecta alone very similar types of societies have arisen quite independently from the mother-offspring relation on more than 30, and in the Aculeate suborder of Hymenoptera alone, on at least 7 different occasions, but in each case more conditions than the mere mother-offspring relation must have cooperated to determine the complete societal pattern.

(2) The futility of accounting for consociative behavior by referring it to

a special social instinct is shown also by the fact that every consociation is a more or less integrated, spacio-temporal system, or emergent, consisting of a number of lower level emergents. This is clearly seen in the case of insect and vertebrate societies, which are really so many epitomizations (2) of many forms of consociative behavior like those exhibited by the multicellular individual, the aggregation and pairing of individuals, the family, with its parent-offspring relations, the food associations (predatism, parasitism, symbiosis), etc. Such components necessarily undergo great deformation, or take on quite novel aspects in the final synthesis, represented by the insect or mammalian society. In human society, of course, the creative psychological factors introduce even more extraordinary complications. In all cases, however, we are dealing with what the philosopher G. H. Mead (3) had in mind when he defined sociality as "the capacity of being several things at once."

Insect and mammalian (including human) societies have a peculiar interest because they happen to represent the highest types of behavior to which the two most important animal phyla, the Arthropoda and Chordata, have attained. Of course, the differences between these phyla are enormous, as is evident from the disparity between their members in size, structure, longevity and behavior. I shall confine my remaining remarks to one of the most outstanding differences and one that seems to me to be of no little interest in connection with our own social organizations, namely, the high degree of integration and stability of the insect society and the extraordinarily harmonious and self-sacrificing cooperation of its individual members, as contrasted with the mobility, instability and mutual aggressiveness so conspicuous among the members of our own society. Moralists, inventors of Utopias and satirists have never allowed us to forget the ants and the honeybees, because they actually enjoy what is, perhaps, for us poor humans only a social ideal. Until recently the termites were not mentioned in this connection, partly because they were supposed to be ants and partly because their monumental social achievements are confined to the tropics, where the best is like the worst and uplift is unpopular.

Although it has long been known that the social insects are, as a rule, extremely aggressive towards the individuals of other communities, even of the same species, little search has been made for the conditions that have brought about the harmony between the individuals of the same community (4). This is obviously only one of the aspects of the great stability of the social system and the result of a very long history. The numerous fossils now amassed in our museums show clearly that all the main groups of social insects had completed their social organization, their caste differentiation and to a considerable extent also their taxonomic evolution by the beginning of the Tertiary (Eocene and Oligocene), some 50 to 60 million years ago. They must have begun their social organization, therefore, somewhere in the Cretaceous, if not earlier, perhaps as long ago as 80 or 100 million years. Hence, if the age of our own species is put at not more than a million years, we might be tempted to condone the instability and aggressiveness of our societies as expressions of social infantilism or immaturity, but mere time and the fact that the social insects have at least thirty generations to our one can be significant only when taken in connection with the underlying behavioristic peculiarities that made for social stability or instability in the first place. The important difference lies, I believe, in what I shall call the "problem of the male," which has been successfully solved by the social insects but

not by mammal or human societies. The social insects, in fact, solved the problem by two different methods, one of which was employed by the social Aculeates (ants, bees, wasps), the other by the termites.

For obvious biological reasons the female is the social sex *par excellence*, whereas the male was originally and remains throughout the evolution of the Arthropod and Chordate phyla, except in a few fishes, amphibians and birds, the unsocial sex. In many animals, in fact, he might more properly be called the antisocial sex. When the individuals of a species discovered in social organization a new and powerful adaptation to the environment and to one another, the male as a necessary fecundating agent could not, of course, be completely ignored, but his original constitutional differences in the two phyla resulted in corresponding differences in his social assimilability. Among the insects this is clearly seen in the exclusively female societies of the social Aculeates, all of which are really so many taxonomic families of wasps, derived without doubt from solitary wasps of the superfamilies Vespoidea and Sphecoidea. These, in turn, we regard with equal assurance as being descended from the Parasitoid or Terebrant Hymenoptera, which had evolved as early as the Jurassic, some 150 million years ago (as shown by the fossil *Ephialtites jurassicus*), and are still represented in our recent fauna by thousands of species. Now throughout the Terebrant suborder and the solitary Vespoids and Sphecoids we find that the female is larger, more muscular and generally more richly endowed than the male and exhibits an intricate behavior pattern in providing for her offspring, while the male has reduced mouthparts, less specialized antennae, a smaller, less differentiated brain, except for its optic ganglia, and a behavior pattern so meager as to amount to a mere seeking out and fecundating of the female. As if to increase his inferiority complex, the female acquired the capacity to produce viable offspring from unfertilized eggs and developed a muscular-walled spermatheca for the storage of the spermatozoa from a single mating, with glands producing a secretion to keep them alive for several weeks. When certain families of solitary wasps became social, therefore, it was easy to exclude the males from participating in the communal activities and to tolerate them about the nest only in small numbers and for a brief annual season. By enlarging the spermatheca enough sperm from the single mating could be stored and kept alive for months or even years—three or four years in the honeybee, three or four times as long in the ants—to fertilize thousands of eggs. Having solved the problem of the male by reducing him, so to speak, to an appropriated and stored convolute of sperm, the social Aculeates, long before the Tertiary, proceeded to introduce new styles of females by inhibiting the development of the ovaries in the majority of the offspring, which thus became the workers. These were still further diversified in many species of ants as soldiers, or defenders, and workers proper, or nurses and nest-builders. The division of labor thus initiated was utilized in overfeeding and thereby exaggerating the fecundity of the fertile female, or queen, and the rearing of more and more of the sterile individuals to build the nest and feed, rear and defend the successive broods.

The termites, because of their very different phylogenetic origin, solved the problem of the male in an even more satisfactory manner than the social Aculeates. They are closely related to the cockroaches, or Blattoids, and probably branched off sometime during the Mesozoic from the ancestors of the latter, the extinct Protoblattoids. Like the Blattoids the termites have a very in-

complete metamorphosis, their sexes are externally very much alike, and the spermatheca of the female, which is non-parthenogenetic, is more rudimentary than in the social Aculeates and lacks spermophilous glands. These peculiarities, inherited no doubt from Protoblattoid ancestors, seem to account for the fact that the societies of the termites are bisexual instead of female, as in the social Aculeates. The termitary is founded by a male and a female, or king and queen. The king cooperates with his consort in excavating the initial chamber in the soil or dead wood and, being a long-lived insect, continues to live at her side, mating with her from time to time and thus enabling her to produce enormous numbers of viable eggs, which in some African species may be laid at the rate of 30,000 a day. The nymphs hatching from some of the eggs are fed in such a manner as to become kings and queens, which will either found new colonies or eventually take the places of the deceased royal parents of the termitary, but the great majority of nymphs become male and female soldiers or male and female workers, in approximately equal numbers, because their reproductive organs are aborted as in the exclusively female workers and soldiers of the social Aculeates. The termites therefore keep only a single fully developed, monogamous male in the termitary and, as if confronted with a serious problem of male unemployment, have hit upon the happy device of sterilizing most of the nymphs of this sex in their infancy and setting them to work with their equally sterile sisters in the kitchens, dining rooms and nurseries and at building and defending the termitary instead of permitting them to sit around like a lot of social parasites and annoy the females. We may say that the termites are the only animals that have succeeded in completely socializing their males.

Until recently we had little accurate knowledge of the bird and mammal flocks, herds, packs, troops or bands, collectively designated by Espinas as "peuplades." Their organization proves to be very different from that of the social insects, because the individuals among the higher Vertebrates are much more highly differentiated than they are among the insects and other Invertebrates. The rôles of the sexes, too, are more specialized. This is especially true of the male, which in the higher Vertebrates is usually larger, stronger, more restless, more inquisitive, more exhibitionistic, bolder, more reckless, more brutal, more pugnacious and less sagacious than the female. He eventually becomes, therefore, a much more serious social problem than he is among the insects. Indeed, he acts like a violent ferment in Vertebrate group life, increasing both its constructive and destructive mobility and accentuating its dynamically stratified organization.

We may select as a paradigm of Vertebrate Society Schjelderup-Ebbe's account of a flock of domestic fowl (5). Close observation shows that every bird in the flock is a personality, determined by its ambivalent dominance-submission reactions in relation to every other bird. Thus bird A can peck bird B and B can peck C, etc. An alien fowl may enter the flock but acquires a definite status or relationship to the other birds only after demonstrating its abilities as a pecker and the extent to which it is resigned to being a peckee. Schjelderup-Ebbe calls the hierarchy of status, which I have briefly described, the "pecking order." There may be one individual, the "α-bird," usually but not necessarily a mature cock, which has the right to peck every other bird, but there is obviously no ω-bird, unless we apply the term to a dead bird. The pecking order, however, is far from being a fixed and constant hierarchy. It is really very complicated, because the interrelations of the birds are often triangular or

polygonal, A pecking B and B, C, but C may be able to peck A, or the series may be ABCDA with a resolution of the rectangle into triangles, ABCA, BCDB, etc. Furthermore, the order is constantly changing with the changing physiological state, or age, vigor and health of the individual birds. The diseased, disabled and aged soon descend through the ranks of peckees, while the young, after a long submissive rôle, promote themselves as rapidly and as far as their strength and pugnacity will permit to the ranks of peckers. Schjelderup-Ebbe noticed that the higher the birds stood in the pecking order, the better their general health and the more self-confident their behavior seemed to be, while those of the lowest rank wore a dejected and bedraggled appearance.

The organization of the herds and packs of the lower mammals is like that of the bird flock, except that we should have to call it a biting instead of a pecking order, or with recent students of mammalian behavior a "scale, or order of dominance." As long ago as 1892, Hudson in his "Naturalist of La Plata," writing of the packs of semiferal dogs kept on the cattle-breeding establishments in Argentina, remarked that "from the foremost in strength down to the weakest there is a gradation of authority; each one knows just how far he can go, which companion he can bully when in a bad temper and wishes to assert himself and to whom he must humbly yield in turn." A dominance scale of fundamentally the same type has been observed in the troops of various monkeys and anthropoid apes but is, of course, more elaborate, as we should expect from the greater physical and psychical plasticity of these creatures. It is scarcely necessary to emphasize the fact that in man the very ancient mammalian dominance scale has not only persisted, but has become even more highly differentiated than in our primate ancestors. We are all born into such an order, the family, and all our institutions—governments, armies, navies, schools, churches, business-houses, factories, etc.—are so many magnificent pecking orders, which condition and regulate our lives and keep our emotions oscillating between elation and misery, according to the position we happen to be holding within them (6).

In order to bring my argument to a conclusion something more must be said about the mammalian male. When mature he naturally occupies a higher rank than the female in the dominance order of the group. Owing, however, to the decidedly unsocial character of his behavior, which manifests itself almost exclusively in voracity, pairing and fighting with other males, he is always, so to speak, socially more or less indigestible. There seems to be no reliable record, at least among the lower mammals, of a male providing food for the female or young or even protecting them. Indeed, after pairing, the sexes seem to become indifferent or even hostile to each other and the female retires to bear, suckle and rear her young in a safe lair or retreat which she alone establishes. She thus forms a family with her young of both sexes and in advanced life may become the leader of a herd consisting of several such female-offspring families (ruminants, elephants, cetaceans, etc.). Here the social organization unmistakably resembles that of the social Hymenoptera, since the male is not a member of the family (7). Even in mammals as high in the scale as bats the two sexes form separate peuplades. Such social ties as the males of these and other mammals exhibit among themselves may be due to social conditioning while they are still young and under the tutelage of their mothers. In the seals and more conspicuously among the apes, as shown by Zuckerman's observations on the troops of baboons (8), and the scattered published

accounts of the anthropoids, the adult males are found definitively installed within the group and giving full expression to their dominance (9). In the troops of baboons each of the mature males, the "pashas" or "overlords," secures as many mature females as possible to form a harem, which he carefully guards and to the outskirts of which the younger and less dominant bachelors attach themselves. As soon as the pasha's vigor declines, they snatch away the females and set up as pashas on their own account. A troop of baboons is, therefore, far from being an urbane and amiable society. The unsocial character of the male reveals itself even more clearly, both among the lower mammals and the Anthropoid apes, when he becomes senescent and impotent and wanders away from the troop or herd to lead the life of an anchorite "rogue." The female, on the contrary, as a virago, acquires a certain male dominance and becomes the matriarch of the herd without serious loss of her social interests.

At first sight human society seems to have solved the problem of the male. At any rate, the reader of many sociological treatises is left with the impression that human groups are uniformly, bisexually socialized throughout. Certainly the majority of men are far more social than the male apes. We have, unfortunately, no knowledge concerning the origin of the human species or of the social rôle of the sexes in its earliest groups. Although authorities agree that none of our extant anthropoids can be in the direct line of man's descent, there is considerable difference of opinion in regard to the point of divergence of his immediate ancestors from the hypothetical primate stock. Some believe the divergence to have taken place as early as the Oligocene, others not till the Miocene, and then from some common ancestor of the chimpanzee and gorilla, while at least one author regards man as a polyphyletic species, derived from several hypothetical primates, each of which gave rise to one of the extant species of anthropoids. Although the character of man's earliest social organization is unknown, the researches of ethnographers, archeologists and historians show that it was in all probability what it still is, a dominance order, or what Sorokin calls a "social stratification," resembling that of the birds and mammals (10). The great physical energy and unequal endowment of the individuals within this order and especially the predominance of the males evidently accounts for the extraordinary restlessness and mobility of human societies (11). Even in primitive human societies there must have been far more cooperation between the sexes than there is among the higher mammals. This cooperation may have had its origin, as Zuckerman suggests, in a division of labor between the sexes at the time when man changed from a vegetarian to a largely carnivorous diet (12), but it seems to me that the pronounced socialization of the male must have been due in great measure to the intensive social conditioning to which he was subjected by the mother and the other members of the family during his infancy and childhood, which are so much longer than in other primates. One is tempted also to look on the matriarchal, or matrilineal type of human society, which, according to many ethnographers, was once universal and still survives among many peoples, as eminently suited to socializing the male. Even in these societies there is a clear division of labor between the sexes, since the males do the heavy work, hunting and fighting, and also function as chiefs and shamans (13).

Be this as it may, however, the male has now become so dominant in our modern patriarchal societies that we may regard them as male societies in contradistinction to the female societies of the Hymenoptera and lower mammals and the bisexual societies of the termites. Furthermore, the manifesta-

tions of this dominance show clearly that the human male has never been adequately socialized. Throughout the ages the aggressive, emotional instability, intense egoism and pugnacity, not to mention other unsocial and antisocial tendencies inherited from his Anthropoid ancestors, have kept society in constant turmoil, so that human history is little more than an interminable record by sober and impressionable males of the abominable behavior of other males. We might, perhaps, divide the members of this sex very roughly into three classes. One of these, the majority, comprises the completely socialized individuals who, in collaboration with the women, maintain the social structure. The second class is very small and comprises less socialized individuals whose dominance is manifested mainly in the intellectual and emotional fields. These males really constitute two ill-defined subclasses, one of which may be said to create the great cultural values (sciences, arts, technologies), the other the great cultural illusions (philosophies, theologies, social utopias). To the third class we may assign a not inconsiderable number of criminals, or individuals of low mental age and with unbalanced endocrines, who in the past have succeeded in wrecking every great civilization. We have all been witnessing recently such an extraordinary display of antisocial behavior by males of this class in continental Europe, the Orient, Cuba and the United States, that further comment is unnecessary.

After I had written the first draft of this paper, I was pleasantly surprised to find that I must have been in somewhat belated telepathic rapport with Professor Ernst Bergmann, of the University of Leipzig, who very recently developed essentially the same thesis, with much greater eloquence and erudition, in a fascinating book entitled "Erkenntnisgeist und Muttergeist" (second edition, Breslau, 1933). He has, in fact, constructed a grandiose "sociosophy" of the sexes out of materials drawn from the remotest by-ways of religion, ethics, philosophy, history and biology (14). I should differ with him, perhaps, in placing more emphasis on the fact that all progress in our civilized societies is initiated by a relatively small portion of the male population, whose restlessly questing intellects are really driven by the unsocial dominance impulses of their male mammalian constitution and not by any intense desire to improve society. Female societies, like those of the Hymenoptera and lower mammals, and bisexual societies, like those of the termites, are indeed peaceful and harmonious, but also stationary and incapable of further social evolution (15). Even the matriarchal clans of primitive man advanced towards civilization only after they had become patriarchal (16). We seem to be confronted with the trilemma of either finding some means of socializing our males more completely, or of returning to a more unprogressive bisexual society like that of the termites (Russia already shows a suspicious approach to such a society), or of lapsing into something like Spengler's Fellahin society. For thousands of years attempts have been made to socialize the unsocial and antisocial males by fasting, prayer, sermonizing, systems of ethics, idealistic philosophies, legislation, prohibition, punishment and discipline, but with very indifferent success. It is always in order, of course, to suggest a thoroughly reorganized mental and physical education of the young as a cure for our social ills (17), but it is equally probable, as Bergmann insists, that only an adequate knowledge of the biology and psychology of the sexes will enable us to solve the problem of the male. Fortunately, the youthful sciences of endocrinology, genetics, eugenics, penology and psychiatry are beginning to provide us not only with this knowledge but also with suggestions for its practical application.

NOTES

(1) Certainly the fact that there are many weaknesses in the organicist analyses of the earlier sociologists, as Keller, Ferrière, Sorokin and others have shown, is no excuse for the modern sociologist's lack of interest in the animal consociations. Recent investigations, some of which are briefly considered in this article, are showing with increasing clearness that the sociologist can still derive valuable suggestions from infrahuman group phenomena. Not only does individual animal behavior prove to be much more subtle than the earlier zoologists supposed, but animal groups exhibit many activities that are very difficult or impossible of analysis in human societies. The animal groups are not only more numerous and more diverse and therefore more richly illustrative of many patterns of social behavior, but also more sharply delimited in space and time than primitive human societies. The animal consociations also possess other methodological advantages, since they can be isolated, their personnel controlled at will and their behavior subjected to experimental investigation. Their shorter life-span, moreover, enables us to study their origin and growth, their pathology and eventual extinction.

The extent to which Sorokin would allow the sociologist to adopt an organicist view of human society is indicated in the following quotation ("Contemporary Sociological Theories," Harper Bros., N. Y., 1928, p. 207): "In bio-organismic theories we must strongly discriminate between two different classes of statements. The first class is composed of the statements that sociology has to be based on biology; that the principles of biology are to be taken into consideration in an interpretation of social phenomena; that human society is not entirely an artificial creation; that it represents a kind of living unity different from a mere sum of the isolated individuals. These principles could scarcely be questioned. They are valid. They are shared, however, not only by the bio-organismic school, but by a great many other sociological schools. In this sense they do not compose a monopoly of the bio-organismic theories, or their specific characteristics."

(2) With the meaning of the term as employed by G. P. Conger in his "A World of Epitomizations," Princeton University Press, 1931.

(3) "The Philosophy of the Present," Open Court Publishing Co., 1932, p. 49.

(4) Exceptions to the latter statement are the slaughter of the drones and the battles between old and young queens in the honeybees, the slaughter of the soldiers by the ant *Pheidole militicida* and apparently also by some termites, the destruction of their own brood by wasps and ants, the devouring of portions of their young brood by colony-founding queen ants and the assassination of the nest queen by her own workers and the adoption of a parasitic queen in her place by some host ants. All these cases, except the last, are motivated by the failure of the food supply at certain times or seasons and are really attempts to preserve the life of the colony. The last case, according to Forel, is due to the preference of the workers for a small, young and very fecund queen instead of their own large mother, because the latter demands more food. Perhaps, however, other attractions of the parasitic queen, such as agreeable secretions, which, like those of some myrmecophilous beetles, tend to pervert the appetites of the workers, may be the true reason for adoption. We are, nevertheless, dealing with a distinctly pathological condition.

(5) T. Schjelderup-Ebbe, "Die Despotie im sozialen Leben der Vögel." Arbeit. biol. Grundlegung der Soziologie, Hirschfeld, Leipzig. X, 2, pp. 77–140.

(6) Notwithstanding the development of dominance in man it seems only occasionally to have attracted the attention of sociologists and psychologists till recently. In social psychologies it was often briefly treated as the "instinct of self-assertion" till those *enfants terribles*, the psychoanalysts, and especially Adler, began to rear an imposing doctrine upon it. Now we are all familiar with the exaggerated or pathological manifestations of dominance—the superiority complex, self-maximation, the regal self, the Jehovah-complex, the Messianic complex, the God-complex, the masculine protest, exhibitionism, sadism, etc. Its more temperate, normal aspects certainly did not escape some of the philosophers, such as Hobbes, Schopenhauer, Nietzsche, Hocking and Spengler, but their pet term—"the desire for power" or "the will to power"—and those of the moralists, psychologists and historians—egotism, egocentricity, self-interest, ambition, emulation, competition, elation, aggressiveness, greed, pride, vanity, display, authority, prestige, coercion, supremacy, dominion, tyranny, conquest, oppression, sovereignty, despotism, militancy, etc.—are so familiar that they lack the thrill of those fine psychoanalytical terms. Several social psychologists—McDougall, Tansley and others—regard dominance or self-assertion as an "instinct" and contrast with it another "instinct," "self-abasement," variously designated also as submission, subjection, subordination, allegiance, subservience, obedience, compliance, inferiority complex and masochism. If we regard dominance as an instinct it is certainly one so primitive and fundamental as to characterize all living substance and to be equivalent to self-preservation. Seneca said "*vivere militare est*," which is paraphrased by

Ortega y Gasset when he defines life as "the struggle, the effort to be itself." Adler admits that "the will to self-determination in the narrower sense, *i.e.*, to power, is a mental factor which . . . derives from far down in the animal world." Spengler, in his "Man and Technics," expresses the same thought more explicitly when he says: "The free-moving life of the animal is struggle, and nothing but struggle, and it is the tactics of its living, its superiority or inferiority in face of 'the other' (whether that 'other' be animate or inanimate Nature), which decides the history of this life, which settles whether its fate is to suffer the history of others or to be itself their history. *Technics is the tactics of living;* it is the inner form of which the procedure of conflict—the conflict that is identical with Life itself—is the outward expression." Curiously enough, Ellwood ("Sociology in its Psychological Aspects," D. Appleton and Company, New York and London, 1912, p. 228) regards the "instincts" of self-assertion and self-abasement as "peculiarly human." At this point we naturally ask whether it is possible to distinguish at all clearly between self-preservation of a living and that of any stable physicochemical system. Whereupon the consideration that mere existence necessarily implies some degree of self-preservation or self-maintenance at once lands us in the cactus-thickets of philosophy. We all at times experience the "purecussedness" of inorganic bodies and feel a dim mental affinity with the animistic savage. And what is "instinct," as employed in most biological and psychological literature, but camouflaged animism? Others are very doubtful whether there is a special instinct of self-abasement. "From the beginning," A. H. B. Allen ("Pleasure and Instinct," Harcourt, Brace and Company, New York, 1930) says, "every living thing has only existed by asserting itself and refusing to give way to others," and submission is imposed by the superior force of the dominant organism. "It is always possible to yield in a combat; and the yielding can hardly be called a separate instinct." "Submission is nothing but the negative of self-assertion; it is the giving up of self-assertion, accompanied by the opposite feeling, that of pride negated or taken down." Moreover, it has not been demonstrated that self-abasement is innate, though in its pathological form, as masochism, it is accompanied by a positive feeling of pleasure. Other emotions such as fear may also accompany submission. C. R. Carpenter, one of the younger behaviorists, regards both dominance and submission in the black howler monkeys of Panama as merely positively and negatively conditioned reflexes and hence as learned reactions, or habits. That this opinion may be correct is indicated by the phenomena of domestication, which depends on man's dominance and the animal's submissiveness. In some of our domestic animals this submissiveness has to be secured by renewed "training" in each generation, in others it may require only a slight reconditioning of the animal's juvenile behavior.

(7) A few writers (*e.g.*, Jennings) do not regard the mother-offspring group among ants, bees, etc., as a family, probably because it contains no father. They seem to understand the term only in the derived juristic sense of the Latin *familia*, which stresses the presence of the male progenitor (*paterfamilias*) who is not like the mother "*naturâ vera et certa,*" but "*jure verus et certus,*" that is, a legal fiction. Originally the term *familia* meant the servant body of a household and has since acquired numerous meanings (see Century Dictionary). Since a widow and her children are called a family, objection to using the same term for the mother-offspring group of the social insects and lower mammals would seem to be mere quibbling.

(8) S. Zuckerman, "The Social Life of Monkeys and Apes," New York, Harcourt Brace and Company, 1932. For data on the anthropoids see R. M. and A. W. Yerkes, "The Great Apes," Yale University Press, 1929.

(9) Male dominance may have many different expressions. Even the voice may become an implement of this urge. The vertebrate male must have discovered long ago that his voice was more powerful and terrifying than that of the female and that he could often employ it effectively without endangering his hide. His voice proved to be particularly useful when his possessions were disputed by other members of his group. This is seen in many Vertebrates ranging all the way from the growling dog guarding his bone, the male song-bird preempting his breeding territory and the male howler monkey preempting the feeding area of his troop to the dogmatic, hortatory theologian defending his knowledge of the supernatural and the vociferous political orator defending his equally fictitious knowledge of economics and state craft.

Another interesting aspect of dominance in an extreme and sadistic form is exhibited in the courtship and mating behavior of animals. Major R. W. G. Hingston has made much of this aspect, which he calls "hostility" in his recent book, "The Meaning of Animal Colour and Adornment," London, E. Arnold and Company, 1933. I quote a few paragraphs (pp. 325–326) from the conclusion of his thirteenth chapter: "The sex act is a double act. It consists first in an act of male rivalry, second an act of sexual union. The two are interlinked and the second is dependent on the first. In all animals there occurs a preliminary rivalry—by

physical battle or threatening gesture or vocal utterance—before actual union is fulfilled. Often this rivalry is fierce and continuous. Several species have special assembling-grounds where the males come together for the sole purpose of developing this first stage in the act. The usual view of all this fighting is that it takes place for the possession of the females or the holding of breeding territories, and these undoubtedly are manifest results of it. But I am confident that, apart from these results, it fulfils a biological necessity of far deeper and wider significance. Is it likely that male animals would keep special arenas for the purpose of going through elaborate gesticulations or would indulge in long singing-contests unless their emotional natures demanded that there must be an outlet for their developing passions?

"All this rivalry then is of deep importance. And its importance, I believe, lies in the fact that it brings to full development that hostile emotion which is the first step in the act of coitus. This hostility is directed to the rival male; nevertheless, it is a fundamental step in the development of capacity for fertile union with the female. Rivalry does not occur just because a rival is present; I believe it must occur if full sexual activity is to develop. Rivalry and coitus are biologically interdependent; the one must be developed and brought to perfection in order that the other may be fully efficient. Indeed, I regard the act of coitus as the final step in the act of battle. It is, as it were, a demonstration to the male of the final achievement of his hostile intentions, satisfying all that he has battled for so intensively and standing in his emotional nature for the defeat and annihilation of his rivals. The sex act is then not a mere male-female contact, but rather an act of fierce hostility directed for a time against rivals of the same sex and receiving complete fulfilment through an act of union with the opposite sex. But fundamentally and all through the sex act has a hostile content.

"This view will later throw light on so-called courtship behaviour and on the important problem of sterility. Also it will help us to understand why the generative organs have this dual function. The testes not only secrete the sperm, but also control the fighting machinery. Why should these two functions be allocated to one organ unless the two functions were closely interknit in the fulfilment of the generative act? And on our view they are interknit, in that the efficiency of the sperm-producing function depends on the fulfilment of the act of battle."

(10) P. Sorokin, "Social Mobility," Harper Bros., New York, 1927. "Any organized special group is always a stratified social body. There has not been and there does not exist any permanent social group which is 'flat' and in which all members are equal. Unstratified society, with a real equality of its members, is a myth which has never been realized in the history of mankind. This statement may sound somewhat paradoxical and yet it is accurate. The forms and proportions of stratification vary, but its essence is permanent, as far as any more or less permanent and organized group is concerned. This is true not only of human society, but even in plant and animal communities." The term "stratification" is unfortunate, perhaps, in that it suggests a rigid or static order. Professor Sorokin, of course, makes it abundantly clear in his book that he is dealing with a dynamic organization.

(11) The greater physical energy of human individuals compared with those of other animal species is significant. As Pitkin says: "Man has built up, through the ages, a huge fund of physical energy with which to maintain himself against the hostile forces of his environment. He possesses more than three times as much, for each pound of his body weight, as any other mammal which has yet been measured. For each pound of flesh in a horse, cow, dog or cat, there is considerably less driving power through adult years than there is in five ounces of human flesh. (The exact ratio seems to be 2: 7.75, according to Rubner.)"

(12) Zuckerman, *loc. cit.*, p. 316: "At its lowest level, according to most authorities, the family of human society was monogamous. If reason played a part in determining the nature of the human family unit, it is very probable that it was guided by the demands of man's omnivorous diet. The polygynous gorilla or baboon can guard his females from the attentions of other males while they forage together for fruits and young shoots. Primitive man, who, as his Palaeolithic arts display, was an animal largely dependent on a diet of meat, would not have gone hunting if in his absence his females were abducted by his fellows. Reason may have forced the compromise of monogamy."

(13) *Cf.* R. Briffault, "The Mothers," 3 vols., London, 1927; abridged edition in one volume, Macmillan, 1931, and J. H. Ronhaar, "Woman in Primitive Motherright Societies," Holland and London, 1931.

(14) Bergmann follows a German convention which seems to require the academic philosopher to write and lecture in a Dionysiac style. In the following translation of an average passage (pp. 130, 131) I have preserved the meaning, but have been unable to prevent the temperature from dropping several degrees below that of the original. I have relegated it to a footnote, because it seemed still too warm for presentation to a male scientific gathering. "And we shall always have to

maintain that the tragic fundamental tone of the male's dramatic, ambiguous, exposed and precarious existence, based as it is on struggle and the elimination of his rivals, will forever prevent the emergence of a sane and happy communal life as displayed in the consummate victory of the maternal spirit, the joyous order and exuberant will to service of the social Hymenoptera. Of all this, indeed, little enough is to be seen in our modern social state, which is created and motivated by the awful splendor and grandeur of the male sexual tragedy, which manifests itself objectively in a perpetual war of the classes, in strife and masculine competition, and subjectively in the restlessness and conflict arising from the cravings and vital anxieties of the male sexual impulses, which are continually gnawing at the social order and hastening its break-up. Men created history, says Mussolini. We answer: Certainly but what kind of a history! One written in blood and tears. Men created religion. Certainly, but what kind of a religion! Thousands of years of contemplation of the hereafter, inspired by worldly anxieties and dread of death. Men created the state. Certainly, but what kind of a state! A strange, misbegotten, anti-state, without vitality, a compromise-and-bastard state that follows neither the life plan of the sexes, nor a just apportionment of the sexual rôles, nor motherright. And the peculiar tragedy of the human race evidently lies in the fact that the female sex never will and never can create history, religion or a state. If the masculine spirit of intellect and leadership does not itself initiate a great change in human culture by transcending the constitutional male idiosyncrasies and by a true interpretation of the cultural trends of religion, morals and the state in obedience to the basic biological requirements, then, *finis humanitatis!* The signs of the times seem to point to a change but they can be correctly interpreted only with the aid of the key-science, which is the sociosophy of the sexes.''

(15) The insect societies might be called centripetal as contrasted with the centrifugal societies of vertebrates. The stability and high integration of the former are symbolized by the nest, which in all its forms—formicary, vespiary, apiary, termitary—is a communal ''Gestalt,'' a unitary, organized whole peculiar to the species, though constructed piecemeal by the sterile members of the colony. Somewhat similar structures are made by a few birds but not by mammals, because each female makes and occupies her own lair or burrow. Our cities with their separate family dwellings or apartments are not, therefore, strictly comparable with the nests of the social insects. This is true even of the communal houses of certain savages.

(16) ''The mother-family came naturally to be, by spontaneous growth out of antecedent conditions. The mother-clan persists indefinitely without any interruption, unless it dies out entirely. A father-family, on the other hand, necessarily breaks up every three or four generations at longest. The former is stable and enduring, like the sex upon which it is based; the latter is active and variable, prone to movement, raiding and eventually to conquest. In its broadest features the mother-family is conservative, traditional and tends to equality in many respects, whereas the father-family is enterprising, progressive, sets free individual energy, and therefore promotes inequality.

''The limited communalism of the mother-family, chiefly as respects food, wastes capital where it does not prevent its accumulation; the energy of men is not stimulated. Its garden-culture by women is only a premonition of agriculture; tillage proper does not begin until men take it in hand. The mother-family has little history, because its character is a perpetuity of sameness. There is slight division of labor in it and therefore little societal organization. It is exogamy and the father-family which begin competition, combination, cooperation and organization. The evolutional movement which we call progress gains momentum with the father-family. War under the mother-family is caused by bickerings over emplacement and blood-revenge; captives are killed or tortured and only exceptionally adopted or enslaved. War has the character of raiding merely. In the father-family, war is less impulsive and is more organized and planned for a purpose by the authority on the ground, and is prosecuted more perseveringly. Its purpose is plunder and, at length, conquest, and its results subjugation, domination, enslavement and eventually the construction of territorial states. Slavery is the connecting link between the economic and militant forces in the evolution of society. Since family organization moves at the same time through the change which we are now viewing, the total organization of society undergoes a transformation which is difficult to embrace and understand with due allowance for all the elements in it.''—W. G. Sumner and A. G. Keller, ''The Science of Society,'' New Haven, Yale University Press, 1927, Vol. III, p. 1984.

(17) For an interesting account of the proposals of philosophers and educators see Will Durant, ''Philosophy and the Social Problem,'' the Macmillan Company, New York, 1917. A very suggestive approach to the philosophical biologists' view of ethics is given in Trigant Burrow's ''Crime and the Social Reaction of Right and Wrong,'' *Journal of Criminal Law and Criminology*, 24, 1933, pp. 685–699.

THE BIOLOGY OF PRIMITIVE HUMAN SOCIETIES

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It seems to me that many of the main trends of scientific studies are peculiar—not to say perverse. The pursuit of science and of knowledge in general is, I suppose, an idiosyncrasy exclusive to the genus Homo. Scientists are all men: they admit it and are, presumably, not altogether dissatisfied with their zoological status. However, in spite of the fact that science is of man, the direction of scientific endeavor seems to be mainly centrifugal or perhaps homofugal. I mean that the quantity of scientific interest in any phenomenon or in any conglomeration of matter seems to vary directly with its remoteness from man himself. Thus there are scores if not hundreds of scientists who are looking for new stars and investigating spiral nebulae, for every one who is studying anthropoid apes. Popular interest wallows in the eccentric wake of professional science. The Century of Progress Exposition was nightly illuminated by a ray from Arcturus in the pompous setting of the Court of the Sciences, amid the applause of gaping thousands; the obscure little tent among the side shows which housed the great anthropoid apes was illuminated by such of the sun's rays as could penetrate its canvas, and was patronized during my two visits only by myself and a few straggling urchins.

Again, while one may admire the concentration of biological interest upon algae, annelids and crustacea, he must deplore the neglect which falls to the lot of mammals, primates and man himself. The only quantitatively appreciable biological studies which have been directed upon man are those of medicine and surgery—and these are inspired not so much by scientific interest as by fear of death and disease. Even in anthropology (the shamelessly impractical investigation of man) the vast majority of workers direct their efforts toward the meticulous examination of what man produces by way of material culture or social organization rather than to the determination of what he is by virtue of being a primate. So we have archeologists who know all about man's pottery, man's weapons and man's implements, and nothing about man himself; ethnologists who are preoccupied with systems of kinship, terms of relationship and the dry bones of social organization, and who care not one whit for the living flesh and blood of the social being; linguists who are willing to let him who will make out the meaning of language, as long as they can study the grammar and the syntax. And, finally, I fear that we have physical anthropologists whose interest in man does not extend much beyond caliper measurements and statistical tables of means, standard deviations and probable errors, and who thereby commit grievous errors which are not probable but certain.

As a matter of fact, modern men living at a primitive or low level of culture—"savages"—have received a greater share of attention from anthropologists than have civilized men, although too often the sequence of cultural contact has been Christianization, exploitation, extermination and finally scientific investigation.

It is not my present task to urge the desirability of studying the biology of modern civilized man, pressing though

the need of such a study may be; it is rather my privilege to point out the special opportunities afforded to the student of evolution in the observation of biological phenomena among primitive peoples.

These special opportunities may be classified roughly in three categories, which are, to some extent, overlapping and interdependent. Under each of these categories there may be enumerated and discussed several factors which operate in various biological situations to affect or even to determine one or more of the following systems of primitive man's biology: morphology, physiology, pathology, psychology, sociology. Specifically, the three categories of factors which peculiarly affect the biology of primitive man and consequently illuminate certain obscure places in the evolutionary process are: (a) those which arise from the close relationship of primitive man to his physical environment, (b) those which arise from the geographical isolation of primitive groups, (c) those which arise from the supposed mental and physical retardation and the demonstrable cultural "lag" of modern savages. Clearly these categories are not mutually exclusive and some of the factors grouped under each might well be assigned to another. Our chief interest here is to call attention to biological phenomena in primitive man which seem to spring from these categories of causes or influences, whether or not the specific causative factors can be isolated in one of the three main categories recognized.

I have described the first group of factors which particularize the biology of primitive man as those which arise from close relationship to his physical environment. I suppose that no one will dispute the statement that primitive man lives closer to nature than our civilized *Homo insipiens*. It is incredible, for example, that we should find in primitive society hordes of savages squatting before some bare urban Mother Hubbard's cupboard, tightening their belts or their breech-clouts, while food is rotting in the neighboring fields and professors of agriculture are tinkering with the daily price of gold. The primitive agriculturalist raises what he eats and eats what he raises; he does not raise that which he can neither eat nor barter nor sell. The primitive pastoralist drinks the milk from his cows or lets the calves drink it or makes it into cheese and butter; he does not pour it out in spiteful libations upon concrete highroads. He does not, in short, behave like a civilized human being.

Granting, then, that savages are more or less what their name connotes, what are the biologic implications of their environmental symbiosis? The first of these is, I think, the untrammeled operation of natural selection. By this I mean that the individual savage survives for the most part through the hereditary toughness of his organism and through the ability of that organism to batten upon or "eat off" its environment, that is, barring accidents. The savage engages from birth in a single-handed battle against his environment, unabetted by synthetic substitutes for deficient mother's milk, without benefit of orange juice, spinach and pediatricians. He grows up, if at all, in full possession of his tonsils and his appendix. In brief, he is bereft of, or secure from, modern scientific medical attention. Consequently, the savage, in the structure of his organism and in its functioning, presents an object lesson in those physical and physiological variations which have survival value, and in those which are, at any rate, indifferent. Some of the material of this exemplification of natural selection will be discussed, if time permits, in the body of this paper.

Another factor which arises from the

peculiarly close relationship of primitive man to his environment is relative uniformity of physical adaptation. The biological effect of this factor can be illustrated best by the contrasting diversity which civilized man exhibits in this respect. In our society division of labor effects stringent occupational selection, which is, in part, physical. Thus a professional pianist will have an extraordinary muscular development of the fingers, wrists and forearms; a ten-day bicycle-racer, of the thighs and calves; a jockey must be undersized and light; traditionally a policeman is likely to have flat feet. A few years ago I undertook a physical survey of the criminals of ten states. This involved also the necessity of securing adequate samples of the civilian population of similar ethnic origin with which to compare the physical characteristics of the delinquents. It was found to be extremely difficult to round up for measurement a sufficient number of suitable subjects for inclusion in this civilian check sample. One of my energetic and ambitious young field workers managed to get permission to measure the firemen of Nashville, Tennessee, for comparison with criminals from that state. However, this check sample has proved rather unsatisfactory, principally because the firemen are extraordinarily fat. Whether this corpulence is an effect of sitting in the fire-houses all day playing checkers, or the natural result of selecting a body of men on the basis mainly of political affiliation, or what not, I am unable to say. At any rate, without laboring the point, it may be stated that the adult male population of urban residence in civilized countries is differentiated physically by occupation to such an extent as to render it quite impracticable to examine the physical characteristics of large groups without making careful allowance for the specializations which may be due to occupational composition.

On the other hand, savages are likely to show physical adaptations which are uniform in groups rather than diversified in individuals. If one of a group shows variations of the femur and tibia which may be attributed to walking with a bent-knee gait, the chances are that all or nearly all of the group will show in varying degree similar adaptations, because they all live in the same kind of country and their bodily habits are similar. Lack of occupational specialization does not bring about the multiplicity of individual variations and adaptations which are very baffling to the anatomist or physical anthropologist who is working over the skeletal parts of tame whites. This simplifies the problem immensely for the student of functional adaptation, since in any primitive group he is likely to be presented with a large range of similar variations which he can analyze and interpret and from which he can generalize with comparative safety. It provides him with adequate and representative samples of the same modifications. Any anonymous skeleton of a white derived from a dissecting room is likely, on the contrary, to present a combination of morphological variations apparently due to physiological causes, which are inexplicable without the knowledge of the occupation of the individual who manifested them. I have an articulated skeleton in my laboratory which shows such peculiarities of the thigh bones and certain other parts that I have vacillated between speculations as to whether the man in life was a tailor, a Turk or one of those Russian performers who do that peculiar squat-and-kick Cossack dance. Alas, these poor Yoricks! We did not know them well, or at all, and we can make very little of their remains.

Sir Arthur Keith relates that he examined the supposed mummy of the Pharaoh of the Exodus and identified him as the veritable Pharaoh who re-

peatedly "hardened his heart," since he showed clear signs of arterio-sclerosis. But even this exact pathological-historical correlation involves a slight difficulty, since the mummy in question was not recovered from the bottom of the Red Sea.

The uniformity of the organic regimen in savages permits us to make reasonably certain deductions as to the relationship between their diets, their habits and their physiques. The Eskimo, for example, presents an excellent opportunity for studying the effect upon the body of an almost complete subsistence upon fish and flesh—generally raw. Many of the American Indians lived principally upon maize; others depended largely upon buffalo meat, while still others had as their staple of diet salmon or manioc. Certain pastoral tribes of Africa confine themselves almost exclusively to milk, beef and blood; the milk of the camel is the main article of food among some desert nomads; many of the congested populations of Asia live principally upon rice. Of course it is by no means universally the case that primitive peoples have unvaried diets consisting of one or two staple foods. As a matter of fact, many if not most savages eat almost anything which is masticable and will serve to fill an aching void and provide a slight amount of nutrition. Even the latter consideration is frequently neglected in some substances which are devoured by peoples in impoverished environments.

It is hardly necessary to contrast with the local group uniformity in dietetic habits which prevails among primitive peoples, the extraordinary diversity of diets which civilized man can command and does utilize. Modern means of transportation and of refrigeration permit the individual not only to vary his diet to an almost unbelievable degree, but also to indulge in many gastronomic specializations according to his constitutional type, his prejudices and his pocketbook. This again makes the interpretation of the individual's biology difficult if not impossible, unless you know what he eats and how much he eats. Some years ago Professor E. L. Miloslavich devoted himself to a somewhat bizarre anthropometric research—that of measuring the length of the large intestine in various ethnic groups. He found that he was able to classify his material in three main categories: (1) persons with short colons (brachycolic, up to 160 cm), (2) those possessing colons of moderate length (orthocolic, 160 cm–175 cm), (3) those presenting long colons (dolichocolic, over 175 cm). Miloslavich established the fact that medium-gutted types were particularly characteristic of Central Europe (Croats, Slovenes, Czechs, Germans, German Austrians); short-gutted types were at a maximum among Magyars, Asiatic Turks, Asiatic Russians and West Poles; whereas the dolichocolic group included most of the Southeastern Europeans (Serbs, Montenegrins, Russians, Slovaks, Rumanians, European Turks, Ruthenians).

Our visceral investigator was cautious in drawing conclusions from his data, but he intimated that changes in environment may influence the length of the colon, just as head form changes in the children of immigrants born in this country. Thus European Turks tend to show Balkan rather than Anatolian types of colon, whereas East Prussians have apparently added a cubit or two to their colic length, by sojourning in the Slavic region. Possibly diet has something to do with these variations—a statement which brings me to the point of this illustration. It is well-nigh impossible to make correlations of diet with anatomy and physiology in civilized European peoples because of their promiscuous feeding habits. Thus we are left in an unhappy state of uncer-

tainty as regards the significance of our colic lengths; whether, if they are short, it is because we are or ought to be carnivorous; or if there are any vegetarian or frugivorous implications of dolichocoly. Contrast with this the pleasing certainty of deduction which attaches to recent and as yet unpublished researches of my friend, Professor George D. Williams, of Washington University, who has been soaking up the desiccated tissues of some Eskimo mummies from Greenland. Dr. Williams and his colleague, Dr. H. A. McCordock, have identified roentgenographically and histologically a large number of the calcified eggs of fish tape-worm in the liver of one of these defunct Eskimos. Now we know that raw fish is a staple of Eskimo diet. We need not worry about the individual tastes and habits of Eskimos—an Eskimo must eat fish and does eat fish, whether he likes it or not, and he eats it raw. Therefore the incidence of fish tape-worm among Eskimos does not depend upon the idiosyncrasies of individual Eskimos as much as upon the degree of tape-worm infestation of the fishes they eat. In other words, if we find a tape-worm in a civilized individual we can infer only that the person in question has eaten something from which he acquired a tapeworm; but if we find it in a savage, we may plausibly deduce that the same kind of unwelcome guests are probably running riot or living riotously in many of his fellow savages who subsist on precisely the same diet.

A second category of factors which contributes to the peculiar instructiveness of primitive biology is that which arises from the geographical isolation of savages. The first of these factors is the intensification of hereditary traits by inbreeding. This leads to clear demonstrations of genetic factors in the production of physical types and illuminates the causes of racial differentiation. It may be that it is isolation which keeps the savage savage, or it may be that the savage becomes isolated because he is a savage. In any event it is certain that only isolation keeps the savage alive, since he is almost invariably exterminated by contact with civilized peoples. I recently heard a highly educated Pueblo Indian girl comment with gentle irony upon the elaborate celebration of Thanksgiving Day forced upon the Indian children in the government schools of the Southwest. Certainly no savage has reason to be thankful for the invention and development of modern means of transportation or for anything else which has made him accessible to the lethal white. There is even some reason to doubt whether the bringing of all parts of the world close together has been an unmixed blessing to civilized nations. Facile communication is as likely to lead to trouble as to better understanding.

Be that as it may, civil communications corrupt good savages. Isolation means salvation for the savage, and for the biologist who studies him it means that his subjects are protected within the walls of a natural laboratory. Since the only areas which remain isolated today are those which are relatively unsuitable for the maintenance of the large populations of domesticated man, the savage generally has to live in environments which do not favor or permit a great increase in his numbers. Consequently, intensive inbreeding takes place. This effects the isolation of homozygous types. The combinations of recessive characters which result are often very unfavorable, but the persons possessing such combinations tend to be eliminated by natural selection, leaving the dominants purified of abnormalities, monstrosities and serious weaknesses. I have no interest here in arguing the relative merits of inbreeding and outbreeding in human stocks. It is my task

merely to point out that the rapid isolation of homozygous factors in man as a function of the intensity of inbreeding may best be observed among savages.

It seems probable that most of the hereditary physical characteristics which we utilize as criteria of racial types are either favorable variations which have a survival value or indifferent variations which are dominant, or variations which are alike beneficial and dominant. There is little or no chance of appraising the significance of racial variations or of other physical variations in the stew of hybridized populations living under artificial conditions of civilization. Here recessive weaknesses of hereditary origin are obscured by heterozygosity. They are overlaid by dominant traits to such an extent that probably the majority of us are little better than perambulating whited sepulchers. Recessive combinations of inferiorities are in part protected by a fatuous humanitarianism—immured in prisons, insane asylums, almshouses and other public institutions. But many of them stalk or hobble unrecognized through the civilized scene, playing every occupational rôle, but none of them well. Under these conditions genetic observations are well-nigh impossible, on account of the lack of pure lines, the presence of an infinite variety of mixed strains, the complexity of the environmental setting and the benevolent interference of science and social uplift with the operation of a purgative natural selection.

On the other hand, if the geneticist or the eugenist (and I do not mean by the latter a Nordic propagandist) is permitted to make his observations in a relatively homogeneous savage society, he can note the inheritance of features which appear to be racial and those which are suspected to be adaptive; he can judge to some extent whether characters are dominant or recessive, and can even hazard a guess as to the survival value of certain physical variations. If recessive features crop out he can observe the biological fate of those manifesting them, since among primitive peoples there are few if any obstacles interposed in the path of ruthless natural selection. If any physical variation is functionally advantageous, that advantage can be most readily discerned in groups which have not departed so far from the state of nature as to deprive the variation of its utility. If the woolly hair of the Negro has any survival value, that value must be determined by studies in tropical Africa, not in Harlem.

Yet another factor arising from the isolation of primitive groups and contributing to the profit of biological study of savage peoples is the range of environmental accommodations of the human organism which they present. Savages live, for the most part, in the remote places of the world. Wherever there is a place left for savages it is undesirable from the point of geographical location, climate or other detrimental features of the environment. The fever-infested swamps, the tropical jungles with their profusion of disagreeable flora and deadly fauna; the deserts with their poverty of nearly everything except sand and heat, the chilly inhospitality of the circumpolar regions—these are all the homes of primitive man. He has to get along in the regions which no civilized man cares to inhabit. Consequently, primitive peoples live under more diverse ecological conditions than the domesticated members of the human species and of necessity exhibit a wide range of physical and physiological adaptations. Civilized man prides himself upon adapting his environment to himself and it must be admitted that he has had no little success in this direction.

The clearing of forested areas for

agriculture, the irrigation of arid lands, draining of swamps and marshes, utilization of water power, destruction of insect and animal pests, are all methods whereby man utilizes or transforms his physical environment, thereby evading in large measure the necessity of adapting himself to that environment. Primitive or savage man has succeeded in ameliorating his environment to a very limited extent only. This is not necessarily because he is more stupid and less inventive than civilized man (although he may be both), but on account of the peculiarly unadaptable and recalcitrant environments to which he has been reduced. Although the savage may have "a goodly heritage," his lines have not "fallen in pleasant places." Practically all the inhabitable temperate zones and most of the endurable tropics have been wrested from him by his decidedly uncivil, though civilized, brother.

Under these circumstances the savage organism has to shift for itself in the most pestilential and dreary spots which the earth affords. Hence if you wish to find out how the human body accommodates itself to a continued existence generation after generation in tropical swamp lands, you must study certain savage tribes of the Amazon basin or of the Nile headwaters, or of other such undesirable places abandoned to the savage. If you are ambitious to discover the effect upon man of a sunless, steamy, tropical jungle, you may investigate the Negritos of Central Africa or of New Guinea. The influence of extremely high altitude upon the human animal can be ascertained among the relatively simple peoples of the Andes or of the Tibetan plateau.

Among the phenomena which arise from the geographical isolation of primitive groups is the stabilization of hybridized types. Race mixtures are most extensive in civilized society, but usually take place under conditions which make scientific observation very difficult and, frequently, impossible. In the first place miscegenation has gone on so long among civilized peoples that an almost infinite variety of mixed types already exists and pure racial types can not be isolated with any degree of certainty. The hereditary combinations have become so numerous as to defy genetic analysis. This is particularly true in the group of races which are crudely classified as "white." Dr. R. R. Marett has remarked that "a casual observer of savage life is apt to imagine it a welter of amatory confusion."[1] He might well have added that a scientific observer of civilized life is forced to regard it as a broth of mongrel promiscuity. Such a statement applies not only to mixtures between the white races in Europe and in the United States, but also to wider racial crosses between radically divergent stocks in most parts of Latin America and in many Asiatic countries.

It is not only the great diversity of racially blended types which makes the study of race mixture so difficult in civilized countries, but also the social stigma under which wide crosses take place. By a wide or radical cross, I mean an interbreeding of two physically divergent races, such as occurs when a North European mates with a Negro. Such mixtures have taken place wherever propinquity has permitted, but usually in a clandestine and surreptitious manner, because of the superior social and economic position of one of the stocks involved and the depressed status of the other. Consequently, the hybrid offspring of such marriages are socially rejected by the dominant and usually paternal race and are relegated to the subordinate stock which absorbs them by back-crossing. Thus there is little or no stabilization of hybrid types but only a small seepage of blood from

[1] R. R. Marett, "Faith, Hope and Charity in Primitive Religion," p. 77. New York, 1932.

the socially exalted race to that which is socially abased. In course of time such a continued dilution alters the complexion of the recipient race, but only gradually and almost imperceptibly. The great reservoir of so-called American Negroes has been considerably contaminated by this steady trickle of white blood, but not in such a way as to make for the stabilization of a new and relatively homogeneous racial type.

Such a state of genetic obfuscation is not usually brought about by the contact of races under conditions of primitive isolation. One reason for this is that primitive peoples are probably not race-conscious to the deplorable or laudable extent which is characteristic of civilized populations. I mean that they are rather naïvely free from race prejudice until they have learned it from bitter experience. The American Indian was quite ready to take the European literally to his arms until he found out that a civilized embrace was inevitably throttling. Racial crosses effected on a basis of social equality between whites and primitive races have occurred only in areas of isolation where white men have come without women and without the numerical superiority which enables them to assert their dominance and to enslave their savage hosts. Such conditions have been realized in a number of out-of-the-way places and have resulted in the stabilization of some new and biologically interesting hybridized types. Among the most important of these may be mentioned the Rehoboth hybrids of Southwest Africa, the result of marriages of the Dutch with the Hottentots; the inbred offspring of Tahitians and the English mutineers from the warship *Bounty*, on Pitcairn and Norfolk Islands; the Kisarese mestizos, descended from the mixture of a Dutch garrison with the natives of a lonely East Indian island. The study of these three groups by Fischer, Shapiro and Rodenwaldt, respectively, has contributed more to the knowledge of the inheritance of racial characters and the genesis of secondary racial types than could possibly be derived from the investigation of any racial mixtures taking place under the congested and infected conditions of civilization.

Another of the reasons why the stabilization of racially hybridized types is likely to occur among primitive peoples in areas of isolation is because sexual necessity knows no law, and islanders can not be choosers. In small primitive groups no maiden is allowed to wither on the virgin stalk, even if she has a touch of the whitewash-brush. A considerable increment of a new racial stock in an isolated primitive population is fairly certain to result in an amalgamation which transforms the entire group, because that group is small and the population inbreeds until the characters of both racial stocks are distributed about in a new and often homogeneous blend. There is no doubt that the Polynesian race originated thus from a tri-racial mixture of some sort of white or Caucasoid stock with Melanesian Negroid and Mongoloid elements. It is still possible to observe the process of race-making by hybridization in areas where primitive races meet and where the mixture subsequently stews in its own juices.

The last general category of special biological opportunities in the study of primitive man is that which arises from the supposed mental retardation and the demonstrable cultural lag of modern primitive men or savages. I am rather dubious as to the validity of this category, since no one has ever proved that savages are in reality mentally retarded or even inferior in intelligence to civilized peoples. Even if this supposed mental retardation exists in fact, it is difficult if not impossible to relate it to biological phenomena in any significant

fashion. Again, although there can be no doubt that savages are culturally backward, it is by no means clear that *any causal relationship obtains between* the inferiority of their material and non-material culture and certain archaic biological patterns which they preserve. On the whole, it seems the part of prudence to look this difficulty boldly in the face and pass on. For there are, at any rate, a number of vestigial biological features which still persist in savage society but have vanished in civilized communities. These are of enormous interest to the student of evolution. They include a number of certainly archaic morphological characters, some possibly primitive physiological processes and sundry variants of the modern biological family grouping. All these may be classified as survivals. Primitive morphological features, such as protrusive jaws, large teeth, undeveloped chins and small brains, probably owe their preservation in savage groups to a lack of competition with more advanced evolutionary variants. Such scanty genetic evidence as is available seems to indicate that more highly evolved physical characters tend to dominate over those which are less advanced. Thus Negro prognathism is rapidly diminished to the vanishing point in crosses with orthognathous white stocks.

Furthermore, in spite of the vigorous operation of natural selection in primitive society, social selection appears to be in abeyance, at least as far as social selection implies the preferential mating of individuals with highly evolved racial characteristics. Of course social classes and social stratification exist to some extent in savage society, but they are not necessarily, or usually, associated with physical differences, even when the group is racially of composite origin. Correlation of racial physical features with a superior social status seems to depend rather upon the subordination of a culturally primitive people by more advanced newcomers who are racially distinct and who both mingle with the *aborigines and at the same time impose* upon them their own esthetic ideals of racial beauty. This is a phenomenon typical of race mixture under the special conditions described.

However, in a simple savage group which is racially comparatively homogeneous archaic morphological features are likely to be distributed generally in the population and are not subjected to the Mendelian dominance of more highly evolved features brought in by a new race. Nor does any stigma of social inferiority adhere to prognathous jaws and black skins when every one possesses them. It follows that primitive ancestral traits, whether anatomical, physiological or sociological, flourish like the green bay tree in isolated savage societies, as long as they are not detrimental to the survival of the species. "If thine eyebrow offend thee, pluck it out" is a maxim which would not be current in an unspoiled primitive group whose racial features include a thick and continuous supraorbital fringe of hair. Man in a state of nature has never learned to despise those features of his physical inheritance which may be reminiscent of an ape ancestry, nor to exalt and select as eugenic ideals bodily traits which may be the end products of degenerative evolution. This idyllic catholicity of taste in bodily beauty is in happy contrast with the perverted fastidiousness in racial characters which has grown up in certain civilized peoples of mixed racial origins.

In Germany the obsession of race has grown from a morbid inferiority complex to a national psychosis. It so happens that the Germans have fallen into the unfortunate habit of taking their science in general, and their anthropology in particular, too seriously. A most important element of their historical

and political education is the conscious effort to build up in their citizens a physical ideal of the traditional German, tricked out in Nordic racial lineaments and replete with all the heroic virtues of a superman. Thus the official German is tall, broad-shouldered, lean-flanked and clean-limbed (whatever that may mean), dolichocephalic or long-headed, with yellow blond hair, eyes of cerulean blue, fair pink skin (such as one loves to touch), thin, high-bridged nose uncompromisingly straight in profile or with just a hint of the aquilinity that is aristocratic and not Semitic, thin determined lips, long horse face, and an aggressive chin.

Now this is all very attractive, but quite inaccurate. Comparatively few Germans answer this description. Undoubtedly a far more typical Teutonic portrait would be: short, squat, thick stubby limbs, protrusive abdomen, head flat at the back, bulging at the temples, brachycephalic; hair mousy brown, eyes mixed or beer-colored; skin muddy, nose bulbous, blobby; jowls pendant, lips blubbery, chin multiple. Several other descriptions different from either of the preceding would apply to great hordes of true Germans with sufficient exactitude. The facts of the matter are that the area of the present German Reich has been occupied since early Neolithic times—perhaps six thousand years ago—by three or four different racial stocks of the white division of mankind, and by a great variety of mixed types which have arisen from their interbreeding. At no time is there anthropological evidence that it was wholly populated by golden-haired Nordics, although doubtless this element was predominant in Northern Germany up to early historic times. The result of inculcating into the German people this spurious racial ideal of a supposititious Nordicism has been singularly unfortunate. First of all, it has promoted the development of a process of social and sexual selection which depreciates all racial combinations of physical features except one only. The latter certainly does not represent a crystallization of the sum total of racial virtues, whether physical, mental or moral.

This lusting after Nordicism has developed in the German people of non-Nordic physical features (and these include the vast majority) a racial inferiority complex which has vicious outlets in several directions. The most sinister activity emanating from this complex has been the persecution and expulsion of the one element in the German population which is generally agreed by Germans to be non-Nordic, or, of late "non-Aryan"—namely, the Jews. Apart from this unfortunate people every German is his own Nordic and is allowed to explain his deviation from the official racial type in a variety of more or less plausible ways. Most of these have been invented by patriotic German anthropologists, who have been forced to the most astounding subterfuges in their attempts to derive the modern brunet, brachycephal Germans from the traditional blond long-heads.

One of these was the famous but rather unconvincing effort of the Bavarian anthropologist, Ranke, to prove that the Bavarians owed their round-headedness and their dark complexions to a prolonged sojourn in the Alpine foothills. Another ingenious idea related the brachycephalization of the modern Germans to an increase in cranial capacity or brain size. Since a spherical container is the most economical in form, it is quite evident that an accretion of brain mass would tend to transform an egg-shaped skull into one broader relative to its length, if such an increase were accompanied by no general enlargement in body size. However, a slight difficulty in the way of accepting this explanation is the fact

that no increase in cranial capacity or in brain size from prehistoric to modern times has been demonstrated in the German population. One of the most amusing efforts to prove that the German people are blond was the pigmentation survey of six million school children carried out by the Government soon after the Franco-Prussian war. It is well known that in mixed races containing blond and brunet strains, light hair and eyes manifest themselves temporarily in infancy and childhood, but a subsequent addition of pigment causes darkening of hair and eyes in adolescent and adult life. Neither infantile nor Hollywood blondes can be accepted as unquestionable Nordics.

None of these expedients have succeeded in convincing the Germans themselves, or any one else, that they are predominantly Nordic in their racial characteristics. Hence they wreak their inferiority complex upon the Jews, and still the inward clamor of their doubts by waving swastikas and by pulling the beards of ancient Israelites (who probably possess as much Nordic blood as they themselves). This lengthy digression into modern biology is not justified by my subject, except in so far as it emphasizes my point that savage societies offer superior advantages for the observation of racial characters and especially for studying archaic morphological patterns, because in contrast to civilized man the savage is naked and unashamed. And if I have trespassed upon the preserves of the following speaker, I can only plead in extenuation the wilful nomadism of the physical anthropologist, who insists upon a range of investigation all the way from the higher primates to the lower politicians.

I have listed among the special opportunities offered to the biologist in the study of primitive human groups the preservation of physiological processes which are also primitive. In an expansion of this paper I intend to justify this claim to an extent limited by the exiguous amount of physiological research which has been carried on among savages. Frankly it is in large measure an assumption, based upon the indubitable fact that archaic morphological patterns are preserved among savages and upon the rather questionable inference of a parallelism between form and function. I take it that the strongest evidence in favor of a primitive type of physiology among savage peoples is found in the higher percentages of such remote groups which exhibit, apparently, the lack of the blood group agglutinogens, A and B, which occur as dominant mutations and have been diffused throughout the more civilized peoples. The vague and uncertain indications among savages of a partial retention of the sexual periodicity which may have characterized our protohuman ancestors are hardly worth a passing mention, since it is now known that apes and monkeys, like man, make love all the year round. Such indications are probably illusory. But the studies of the relation of sex and the reproductive cycle to the social life of baboons, recently carried out by Dr. S. Zuckerman,[2] point clearly the importance of these factors in the social organization of primitive man. The physiology of reproduction, if it does in fact condition the entire social life of man, may best be studied in the simpler savage groups.

The indubitable survival in savage society of primitive variants of the biological family grouping offers a field for research which still retains many fruitful possibilities for the social anthropologist and for the physiologist. In the minds of most civilized peoples there appears to appertain to monogamy a certain moral sanction not dissimilar to that adhering to the conception of mo-

[2] S. Zuckerman, "The Social Life of Monkeys and Apes." New York, 1932.

notheism. Both are considered to be now as they were in the beginning and ever shall be, world without end. Somewhat more liberal treatment is accorded to man than to the deity, in that the former is allowed to have, at any rate, one wife. This monorail type of belief and practise does not obtain in all primitive societies. If there has been any sort of evolution of the family in man, its stages can be reconstructed only from the investigation of the higher primates and of primitive man, although the disruption of that grand old institution is abundantly exemplified in civilized society. Whether or not these familial variants in savage groups arise from mental retardation or cultural lag is a question I propose to argue subsequently.

So far you have been treated to an effusion or spattering of reasons why primitive man makes the ideal laboratory animal, supported largely by contra-indications with respect to civilized man. I do not wish to give the impression of a mere sadist flagellating civilized man over the shoulders of the savage. The foregoing pages are, rather, in the nature of a preambulatory survey —a sort of preliminary scientific sniff. The opportunities of savage biology should be discussed under the several headings of morphology, physiology, pathology, psychology and sociology. Obviously none of these subjects can be exhausted within the limits of the present paper. It is possible only to exhaust the listener and the allotted time. This much already has been accomplished. I must beg the pardon of my audience for proceeding directly from grace before meat to finger-bowls. If you have been offered nothing more substantial than a menu-card, you are spared, at least, the pangs of indigestion.

MODERN SOCIAL ORGANIZATION

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THE essential traits of modern social institutions derive from the emergence of a free society out of the caste society of the feudal epoch. The most important contrast between the two social orders is in the extent of free mobility, or the opportunity of the individual of superior gifts to elevate his social status and likelihood that one of inferior capacities will, of his own weight, sink in the social scale.

The development of democratic individualism destroyed more or less completely, especially in the newer parts of the western world, the medieval class alignment of aristocracy, clergy, tradesmen, artisans, freeholders and serfs. That was in many respects a society of hereditary classes, in which all but a few individuals remained in the social status into which they were born. There was, no doubt, some mobility or movement from social level to social level. Strong and able men pushed upward from low to high ranks. They did so, however, by the force of their own personalities and against both tradition and social opposition. Such mobility increased with the growth of the towns as the middle classes of merchants and traders grew in numbers and importance, especially after the commercial revolution. In general, however, that society tended to preserve the biological composition of the different social classes in a fairly stable state. The slight mobility which it permitted may warrant the assumption that on the whole the upper classes were by nature slightly more able and gifted than the lower. But such differ-

ences, if any, must have been slight in such populations as those of Europe, where the superposition of race and class was largely a consequence of historical chance and change and, so far as we know, no indication of biological differentiation.

Another important feature of medieval society was the very definite and effective restriction on marriage of the lower orders. The somewhat scanty data available show that while the upper, independent classes married earlier than at present, the lower classes not only married considerably later but often did not marry at all. Restrictions were imposed by custom and law, as well as by the force of a stationary or slowly improving economic situation. Broadly speaking, serfs, cotters and other cultivators of the soil could not marry until a house was made available by death. Pollard notes that during the middle ages "the number of holdings was almost stationary and the number of families fixed."[1] In the towns, guild regulations not only bound apprentices for a long term of years but made difficult the marriage of journeymen. As the guild system reached its height its regulations and requirements for membership became more strict. One of the objects of these regulations was to prevent early marriage.[2] In addition to a considerable number of celibate servants and servitors, there was a large number of religious celibates, drawn mainly from the lower classes.

The emergence of middle-class democracy, reinforced by the transforming power of the industrial revolution, fundamentally altered both these outstanding traits of medieval society. It raised social mobility to the highest pitch and made early marriage the privilege of the lower classes and late marriage almost a necessity of the upper. Democratic society sought the obliteration of class lines and did succeed in destroying most of the remnants of hereditary title and privilege. It sought to establish equal opportunity for all. It asserted its devotion to the doctrine of "the open road for talent." It prided itself on establishing a social order in which men would be rewarded according to their individual merit regardless of their birth and in which positions of power and responsibility would be attained by those who proved their worth in fair competition with their fellows. Its ideal was to give all as nearly as possible an equal start in life and by removing handicaps to enable the best man to win. To these ends it established the system of universal, and even compulsory education, often with scholarships and other aids for the poor but worthy, in order to enable the individual to rise as high as his ability, energy and perseverance would carry him. Democracy was animated by the belief that the main causes of differences in social status lay in differences in the start in life or in environmental circumstances. Men were believed to be by nature equal or nearly equal, so that, if the socially handicapped were only educated and prepared for the competitive struggle of mature life, we should destroy poverty, equalize wealth and spread the benefits of our higher culture more or less evenly through the entire population. This is still a living faith among large elements of the American people.

However, a century of extensive experiment with these ideas leaves us with a society more or less definitely stratified as regards wealth, power and culture. The class differences in most of the objective marks of class seem to be as great or nearly as great as formerly. In actual amounts of property and income they may be even greater. The growth of a complex civilization is accompanied by the process which the sociologist calls

[1] Quoted by Carr-Saunders. "The Population Problem," 280.

[2] *Ibid.*, 281.

pyramiding, or a tendency toward an increasing division of labor, a finer and finer occupational stratification of the population and an increasing difference in the wealth and power of those at the top and those at the bottom of the social structure. While we have had a society in which mobility has been raised to the highest possible level, most of this mobility is lateral, or the movement of men from place to place, or from occupation to occupation, without much change in social rank. We tend to re-form into a caste society while maintaining the outward forms of free mobility. The upward movement of the able, energetic and ambitious has been facilitated as a conscious social policy, while at the same time it would seem to be increasingly true that each class recruits itself mainly from itself. The thesis I present then is that our democratic individualism destroyed a society based on hereditary title and privilege but with considerable biological homogeneity among the classes, and with definite restriction of the fertility of those least able to support offspring, only to produce a society having little hereditary privilege but in which biological differentiation between the social classes has become more and more marked, and in which the fertility of those most fitted by birth and resources to produce offspring has been widely restricted.

All features of our culture have cooperated to produce this new stratification. In the first place, the unparalleled material progress has given a tremendous and long-continued stimulus to ambition. The prizes of life have been very great, and the fields in which they have been offered have been numerous, varied and inviting to men of talent and ambition. During much of the last century new lands and vast new natural resources were being opened up for exploitation. The progress of science and invention created ever new opportunities, as did also the steady improvement and exploitation of capitalist, industrial techniques. All this was accompanied by a rapid increase of population, which, together with a rapidly complicating culture, furnished a continuously expanding arena for the ambitious. There always seemed to be room at the top and sure rewards for those who combined energy, ability and persistent effort.

Then, in the second place, the régime of free competition made these prizes available for all and sundry, regardless of birth. We held these prizes steadily before the eyes of ambitious youth and sought by education, precept and example to stimulate them to their highest efforts. The popular mind was repeatedly thrilled with the stories of men rising from poverty to affluence or from unfavorable social environments to positions of power and honor.

In the third place, universal popular education undoubtedly succeeded in accomplishing to a large extent its conscious purpose of lifting the poor and obscure individual of sound mind and body to a social level corresponding more or less accurately to his capabilities. A century ago those who went to college came almost exclusively from families of considerable culture and nearly all of them expected to enter the professions. With the improvement and extension of educational facilities the backgrounds of high-school and college students became more diverse, until, during recent decades, the colleges have drawn boys and girls of all racial, national and occupational groups. Our educational machinery has thus become, in fact, a gigantic sorting apparatus.[3] All children are taken in at the bottom and a very considerable proportion of them are carried as far as

[3] N. J. Lennes, "Whither Democracy? Does Equalizing Opportunity Create Hereditary Social Classes?" Harper and Brothers, 1927.

their ability, temperament and ambition will permit. So far as education is synonymous with opportunity in our culture, millions have had more of it than they could utilize.

No doubt it is true that the educational machine has not been perfect as a selective device. Some children have been compelled to drop out because of poverty or some unfavorable life contingency. The gradual extension of child labor legislation and the progressive elevation of the ages of compulsory education have, however, sought to prevent children leaving school before the ages 14 to 16. They have reduced the exploitation of children by parents, and in doing so have probably become important factors in the reduction of the birth rate. They have, however, gone far to enable talented children to be discovered or to discover themselves, so that with the increasing provision of scholarship and other aids, gifted boys and girls have been able to rise from the lowest levels to the highest. Moreover, the most extensive researches thus far made indicate that the most frequent cause of elimination from the grades below the high school is retardation because of low mentality.[4] There is an extensive body of testimony as to the general association between brightness and progress through the schools. A fundamental principle which has exerted enormous selective influence through the educational system is that bright children not only learn faster than dull ones but they continue to learn longer. Bright children in general have taken greater interest in educational activities. They have been more readily stimulated; their ambition more easily aroused. The extensive development of higher education, both cultural and vocational, has been accompanied by extensive recruiting of the bright and able from all social ranks. There is much evidence that those who have succeeded well at any given point in the educational scheme have been generally selected for still more education. There is a gradual elevation of the average IQ level from grade to grade. Those entering the high school from the grades excel those who finish the grades but do not go on. So also with reference to those who graduate from the high school and go on to college or special training. Moreover, it has become increasingly true that access to the higher vocational levels has become increasingly dependent on success in passing through the educational machine.

I would not exaggerate the extent of this selection of intelligence. The evidence, such as it is, indicates that a smaller and smaller proportion of those who are mentally capable of doing the work reach each successive grade after the fourth or sixth. If, however, of those having the requisite ability only one half complete the high school and not over one fifth the college, and if a proportion of these are thereby drawn to higher social levels, the upshot of these conditions would be the maintenance of the biological quality of the upper levels by recruits from below. This process would lead inevitably to the relative genetic impoverishment of the lower classes. Unless the genetic principles governing man's traits are essentially different from those of his domestic animals, one may be quite certain that the selective processes above sketched, even if they acted only roughly, would in two generations result in measurable differences in the distribution of the selected traits in the upper and the lower levels of our population.

One may hold that selection has not worked; or he may hold that, even allowing for some selective mobility, the population is an inexhaustible reservoir

[4] E. L. Thorndike (1907), Leonard P. Ayres (1909), Helen I. Wooley (1923), L. Thomas Hopkins (1924), and others.

of gifted and able strains; or he may argue with the social environmentalist that elevation in the social scale is a consequence of favoring circumstances and has little or nothing to do with heredity. None of these positions appears tenable in the light of facts. No doubt there are social advantages and disadvantages distinguishing different elements in the population which tend to perpetuate themselves under the operation of sentiment, law and economic forces. Nevertheless, the differences between our social stratification and that of a hereditary class society seem to be so great as to make any analogy between the two fundamentally erroneous.

It is particularly argued that bad environments have cumulative effects. The poor are poor because their parents were poor. So also with the ignorant, the wayward and the vicious. No doubt there is some truth here. The standard of living in any family strain tends to perpetuate itself. A low standard, for example, is associated with early marriage, with inadequate preparation for economic success and with too numerous progeny. This round of events tends to repeat itself. At the opposite end of the social scale the opposite round of events likewise is repeated. Moreover, it is probably easier to prevent an ordinary person born in high status from sinking in the scale than it is for a somewhat more gifted person to rise.

However, there are certain countervailing considerations. Over against cumulative and continuing effects of a cultural environment may be set both the direct and the indirect effects of heredity. In the American environment opportunity has most of the time been not inconsiderable; education has been nearly universal; and the stimuli to advancement have been numerous. If under these conditions a family remains steadily from generation to generation on very low levels of social efficiency, one may at least suspect that heredity is an important factor in the situation. Conversely, if a family maintains itself from generation to generation on a high social level, amidst the changes and chances of a complex culture, with the necessity of constant readjustment to a changing social milieu, one may suppose that good stock is represented. Heredity in the long run and to some extent either shapes or finds its own environmental level. It is not an accident that investigation after investigation, using different criteria, finds the better stocks in the better environments and the poorer stocks in the worse. Able, energetic parents, taken as a group, not only tend to produce able and energetic children, but they provide for them healthful surroundings and good education. Stupid, unstable or lazy parents tend to have children like themselves and to rear them in less than optimum environments. In a freely competitive social order the environmental status of a family may very plausibly be viewed as to some degree a consequence of its special combination of genetic traits.

Then there is the obvious fact that many thousands have risen and are rising from lower to higher levels, while others are sinking in the social scale. Sheer luck is no doubt a factor here. Nevertheless, by every test we have, whether mental test, educational success or achievement in practical affairs, those that ascend are, on the average, more able than those they leave behind. Certainly, one of the greatest ambitions of average American parents has been for their children to rise to levels of higher social esteem. Manual workers by the millions have striven to give their children every opportunity to move into the soft-hand, white-collar vocations. Finally, we may observe that unless this upward mobility has occurred, then our

vast expenditures for education have been a hideous deceit. If, in spite of our elaborate educational machinery and the multiplication of social service activities, it is still possible to say that those who have been most successful in solving the problems of life in our society are inherently no better than those who have been least successful, then democracy has utterly deceived itself.

Such *a priori* arguments as the foregoing for the natural superiority of the upper levels are strong enough in themselves to convince many, but the skeptical scientist will seek more direct evidence. In the first place, we need some objective marks whereby social levels may be differentiated. For this purpose we may utilize occupation, as in the Army or the Barr scales, or the conventional grouping into professional, business, commercial, skilled and unskilled groups. We may use the amount of education, such as completion of certain grades, high school, college, technical school, university, or professional school. We may use also income, home rating scales, social status scales, and similar devices. All these measures tend to correlate highly one with another. Moreover, they represent the popular and widely approved estimates of social status. Our schemes of education and of economic promotion are designed to lift individuals upward from one such level to another.

If, now, we raise the question whether these levels represent a biological gradation we are confronted with the difficulty of finding satisfactory marks of biological worth. For this purpose it is obvious that no external physical marks, such as hair color or shape of nose, will do. A man's biological fitness for achievement in our complex society can not be judged by his stature nor by the size of his head, even though it be demonstrated that both of these traits tend to correlate slightly with our scheme of social levels. We can not be satisfied merely to say that those who have succeeded best have thereby proven their superiority, because it can be replied that success or failure are often due to good or bad luck, or to a favorable or unfavorable start in life.

The fact is that it takes a combination of qualities to succeed in the free-for-all competitive struggle of modern society. Vigorous health, energy, ambition, perseverance and intelligence are all involved. There is not a little indication that these traits tend to be found associated in the same individuals, but the intensity of the association is as yet far from clear. Terman's mentally superior children proved to be superior also in conscientiousness, perseverance, leadership, sense of humor, physical development, energy and general health. Thorndike says "Intrinsically good traits have also good correlatives."[5] Various studies reveal a greater frequency of physical defects among the mentally retarded than among the normal. The study of the association of traits is a promising field of further research.

The only trait upon which a large amount of evidence is available is intelligence. This is measured by mental tests and by progress through the educational machine. These two measures are highly correlated. They are also found to be useful practical measures and to correlate highly with actual success in the competitive struggle. They correlate highly with any scheme of social levels. However, in spite of twenty years' intensive investigation during which tests and testing technique have been greatly improved and during which the general picture of social stratification revealed by the earlier tests has remained substantially unaltered, there are still many who doubt the value of these measures as measures

[5] "Educational Psychology," III, 408.

of innate ability. To them we may observe that innate intelligence can not in any case be measured directly. It can only be measured by what it does. If we allow for a certain roughness in approximation, we seem bound to say that children who do well the things an intelligent person in our society is expected to do may reasonably be supposed to have more intelligence than those of the same race and community who bungle the same tasks. It must be admitted that mental tests are not a thoroughly satisfactory measure of inherent ability; their results are too much affected by education and training for that. We freely admit their weaknesses, while claiming they are the best measures we yet have. In a later section we revert to the extent to which the IQ level may be supposed ordinarily to be raised by average educational advantages.

If, then, for the sake of the argument at this point we take intelligence tests and scholastic records as roughly indicative of ranking in terms of innate intelligence, we note the correlation of social level with IQ level has been so fully demonstrated by repeated research that it needs no detailed proof here. Mental scales of occupational ratings are in extensive use both in research and in practical vocational placement bureaus.

We may now advance the thesis one more step by noting that marriage occurs for the most part among persons of the same social level. In general people marry within their own status group, according to such measures as cultural and educational attainments, occupational similarity and residential propinquity. These are indirect and very unprecise indices of biological similarity. When the extent of assortative mating is measured more directly, there are found to be sensible correlations between husband and wife for stature, certain other bodily traits, complexion traits, longevity, general health, parental fertility, insanity, tubercular infection, criminality, alcoholism, congenital deafness, feeblemindedness and mental deficiency, intelligence and various temperamental and character traits. This is, on its face, an imposing list, though obviously much mixed as indices of genetic similarity.

The highest consistent correlation is found for intelligence, that being twice as high as for physical traits (stature, fore arm, span, hair color, eye color, longevity and general health) which run from 20 to 30 per cent. On the whole, the conclusion seems warranted that there is a measurable tendency toward the mating of persons of similar mental level. It seems probable that this tendency is more marked on the lower and on the higher social levels than through the middle registers. Lidbetter has shown it to be very marked among the social problem group of London, and this harmonizes with the indications of numerous family history studies of "ne'er do weels" in this country. For the business and professional classes equally convincing evidence is lacking, and the tendency may well be less pronounced. However, it is on the higher levels that mental qualities seem to play the larger rôle in mate selection, for along with them go similarities of taste and enjoyments, sympathy and mutual understanding. As Holmes says: "Mediocrity tends to mate with mediocrity and superior types tend to select their mates among the superior."[6]

Thus far we have argued that the social organization of the past century has favored the upward mobility of the more able and energetic individuals, thus bringing about a tendency toward biological stratification of the population; and that the phenomenon of assortative mating further tends to fix and maintain this stratification. Moreover, it is

[6] S. J. Holmes, "The Trend of the Race," p. 231. Harcourt, Brace and Company, 1921.

implied that this stratification has occurred most clearly with respect to innate mental capacities. The demonstration is far from cogent, however, owing to the present uncertainty as to the relative rôles of heredity and environment in determining either mental level, or any mark of social status.

It would seem, however, that the vast accumulation of research during the past generation supports the generalization that there is a direct relation between success in the modern social order and inherent ability. The very best of educational and social environments can do little for the slow and dull. Those who are dull in childhood tend to remain so, almost without exception, while those who are bright remain bright. We have talked much of equalization of opportunity, and have been inclined to forget that what is opportunity for the dull is not so for the bright and *vice versa*. In reality opportunity must be proportioned to ability. Indeed, the able and energetic find opportunity for self-development where the dull can only vegetate.

Professor Jennings and others have very correctly called attention to the fact that every trait is the result of the co-action of both heredity and environment; and they have cited instances, especially on the subhuman levels, of quite different traits developing from the same genetic basis under the influence of different environments. This has given rise to a wide-spread belief in a more or less indefinite organic plasticity. This view, that the organism is molded by its environment, has been especially welcomed by educators, social workers, a certain group of anthropologists and most sociologists.

Over against such a view it seems more in harmony with the facts to set the doctrine of organic responsiveness. Instead of holding that the environment shapes the organism to its own patterns, it is more accurate to state that the environment can call forth only such responses as the organism is qualified by its genetic constitution to make. No trait for which the genes are wanting can appear, regardless of the environment. Moreover, the correlation between the environmental stimulus and the associated trait is determined solely by the genetic make-up of the organism. Just as the Nordic skin, unlike that of the Negro, will burn but not tan, so the moron, unlike the gifted child, remains a dullard amidst the most perfect environmental stimuli. Millions of American children are subject to musical training, but relatively few reveal musical talent. And what is true of musical ability is true of a long list of capabilities, ranging from the handling of mathematics and abstract ideas to the muscular coordinations required in the manual arts. If it were anywhere near true that brilliant men and women could be produced by education we should now have millions of them.

This is not to say that good environment is not necessary; it is an obvious necessity. At the same time, when one sets himself the task of accounting for such differences as occur among the children growing up in an average American community, he need not forget that their environments ordinarily vary through only a small part of the whole range of possible variations. Nevertheless, from such a community will come individuals with most varied capabilities. The human product may vary 100 or more in IQ, even though the environment is relatively uniform. Moreover, it is an obvious fact that improved environment becomes more important in mental development as the hereditary potentialities become greater. One can state without fear of contradiction that equalization of educational environments will increase the range of individual variations, provided such equalization is in the direction of a gen-

eral improvement of educational facilities.

That mental levels tend to be inherited is supported by the general superiority of children of superior parents and the general inferiority of those of inferior parents. Not long since Professor Raymond Pearl[7] made a very curious attack on the Galtonian theory that superiors tend to breed superiors by attempting to show that 588 of the world's greatest philosophers, poets and scientists had sprung indifferently and according to the laws of chance from all levels of the population. Their fathers were said to be "an average lot of human beings." When, however, these fathers were graded according to the Barr scale of mental rank of occupations, they were found to rank above 93 per cent. of a random sample of the American population.[8] About 70 per cent. of the fathers belonged to the two upper classes in Taussig's hierarchy of occupations and none to the lowest. Pearl's cases were, in fact, strictly comparable to those of Galton, Ellis, Cattell and others, and also to Terman's group of gifted children. The product at the opposite end of the scale is too well known to need citation.

In view of the recent researches on heredity and environment in relation to twin and orphan differences, we can carry the argument to a somewhat more precise conclusion. These make possible a preliminary estimate of the influence of different heredities in determining mental level when environmental conditions are similar, and of the influence of different environments when heredity is similar. This evidence can not be adequately summarized here.[9] The following array of conclusions, each of which seems supported by adequate evidence, suggests that the IQ level is, by and large, little affected by such environmental differences as commonly occur in American communities. The mental resemblance between random pairs of unrelated children of a community is around zero; that between sibling pairs is around 50 per cent.; that between fraternal twins is about 60 per cent.; that between identical twins is much larger, ranging from 80 to 90 per cent.; for the siblings and twins the mental resemblance is somewhat higher than that for physical traits, measured by height, weight, respiration and pulse rates, but is nevertheless of much the same numerical order; there are slight changes, if any, in the degree of mental resemblance between twins as they grow older, though their continuance in the same schools and homes ought to make older twins more alike than younger; there is almost the same degree of resemblance between twin pairs in those traits believed to be little influenced by training and those believed to be much influenced thereby. Research to date indicates that the IQ differences between identical twins reared together average roughly about 5 points, or about the same difference as that between two closely consecutive measurements of the same individual. Ten pairs of identical twins reared apart were found by Newman and others to differ, on the average, by about 8 points of IQ, while non-identical twins reared together are found to differ, on the average, by about 10 IQ points and siblings reared apart appear to differ little more than those reared together. In all cases the range of variation is, of course, much greater than the foregoing average differences. Moreover, different schools of opinion put different interpretations on all such data. On the whole, the mass of the evidence seems to me to support the view that heredity is an important fac-

[7] "The Biological Basis' of Superiority," *American Mercury*, 12: 257–266, 1927.

[8] D. G. Paterson and E. G. Williamson, "Raymond Pearl and the Doctrine that 'Like Produces Like,'" *American Naturalist*, 63: 265–273, 1929.

[9] For a most excellent summary, see Gladys Schwesinger, "Heredity and Environment," The Macmillan Company, 1933.

tor, if not the most important factor, in accounting for the differences in mental level among persons living under somewhat similar cultural conditions.

We may conclude this very inadequate summary of the evidence relating to mental level by expressing agreement with the finding of Barbara Burks that "the total effect of environmental factors on standard deviation up and down the scale is only six points." That is, about two thirds of the variations in IQ level due to such differences in home, education and other social influences commonly found in American communities do not exceed six points. In extreme cases such influences may account for as much as 20 or even 27 points. Heredity, on the other hand, obviously accounts for more than 100 points of variation.

The evidence thus pointing to an increasing biological stratification of the population is extensive. Our thesis is not designed in any way to validate the iniquities and imbecilities of the present social order. Nor is it a criticism of education, social work and other humanitarian activities. These rest securely on grounds of social necessity and benefit. Only those who pray for a dictatorship of the proletariat, presumably under their own benign guidance, need take exception. Its practical implication is the desirability of giving some attention to the respective fertilities of different social levels in a society that strives to maintain an open road for talent and at the same time suspends the operation of natural selection among the less capable. The biological resources of the population are not inexhaustible.

No doubt there are still considerable amounts of uncultivated talent in our midst. At the same time, I am inclined to think that the rapid progress of the last century is due in part to the successful exploitation of an unusual proportion of the latent abilities of the population. Talent has been found, stimulated to high endeavor and induced to work at high pressure under the shibboleths of achievement and efficiency. Then we have proceeded to sterilize an increasing percentage of the ablest and placed others of them under social conditions where their offspring have been too few to replace themselves. There has been a constant necessity of replenishing the deficit of the upper levels by masses of recruits from below. Galton advanced the opinion that the Inquisition was a factor in prolonging medievalism in Spain; and many have seen in the slaughter of the Russian intelligentsia and the recent expatriation of German scholars serious blows to the higher cultural activities of those countries. Far greater, in the long run, is the loss to this country because of the thousands who every year fail to be born among those, who by every mark of hereditary fitness and social superiority, are qualified to produce the natural aristocracy of the future.

EARTHQUAKES IN CALIFORNIA

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EARLY in the morning of April 18, 1906, one of the greatest fires in the history of the world broke out in San Francisco. It burned more than four days before it was brought under control. Unusual features were associated with it—streets were fissured, buckled, bent into wavy surfaces, and, where built on made land along tidal estuaries, warped laterally several feet down stream. Water mains outside the city were collapsed and buildings far from the area swept by fire were cracked, broken and tumbled down. In short, even the most loyal San Franciscans were constrained to admit that the outbreak of fire had been preceded by "a little shake," as I heard one man euphemistically describe it. Hardly had the fire ended when news came of a great crack in the earth southwest of the city—at first a vague, almost incredible rumor, but soon definitely and in authentic form—a long, straight surface fissure, or narrow belt of fissures, running southeastwardly for miles on end. Thus came dramatically to notice the surface trace of the San Andreas fault, broken anew in 1906. This fresh break at the surface was found to extend from the vicinity of San Juan Bautista in Monterey County northwestward for at least 180 miles, more likely for 300 miles or more, dying out probably under the sea—running past the Golden Gate under the ocean from Mussel Rock south of San Francisco to Bolinas Lagoon northwest of it. In the city it is still popular to call this event the "fire"—but the world knows that Central California then experienced an earthquake of major rank—though many greater shocks have occurred elsewhere. We know also that the immediate source of the destructive shaking was the San Andreas fault, along which for many scores of miles sidelong slipping of the adjacent crust blocks extended downward to depths measured in miles. The maximum horizontal offset was about twenty-one feet, near Point Reyes Station northwest of San Francisco.

Study of this earthquake could not fail to suggest close relationships between the many earthquakes on record in the annals of California and the numerous geologic faults of recent development which traverse and bound its mountains. Nevertheless, any attempt to fix the sources of particular shocks upon particular faults bristles with difficulty, for the shocks chronicled commonly were felt over extended areas and their descriptions usually lack adequate details. Also the faults are numerous and in many places closely spaced. Efforts to this end made it clear that intensive study of the occurrence of earthquakes in this province, with the close location of shock sources and their relation to the geologic structure, would yield results of importance at once to science and to public welfare. Such work in seismological research, conducted by this institution—in cooperation with numerous agencies, among which the California Institute of Technology, the U. S. Geological Survey and the U. S. Coast and Geodetic Survey are outstanding—is an outcome of the investigations set in motion by the earthquake of 1906. This is a small but important benefit to balance against the disastrous consequences of this shock.

The first problem confronted in this program of the intensive investigation of

COLLAPSE OF NORTHWEST CORNER OF SAN MARCOS BUILDING
A BUSINESS AND OFFICE STRUCTURE IN SANTA BARBARA, CALIFORNIA: SHOCK OF JUNE 29, 1925. AN EXAMPLE OF REINFORCED CONCRETE CONSTRUCTION OF INDIFFERENT QUALITY—BADLY DESIGNED TO RESIST EARTHQUAKE ACTION.

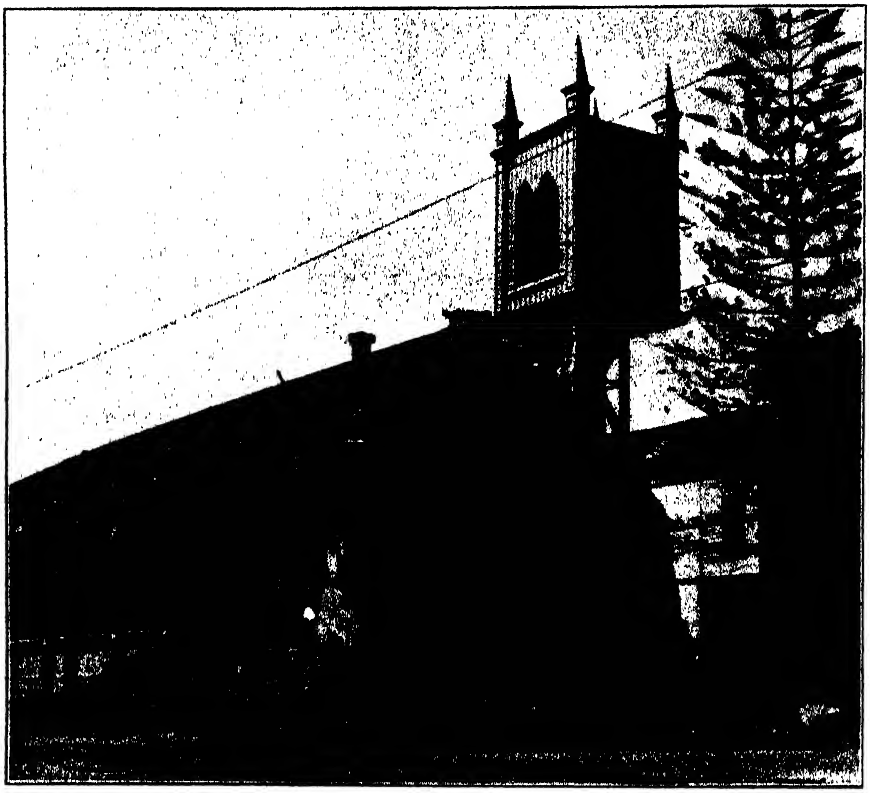
local earthquakes in a restricted province, subject to frequent shaking, was the development of instruments and instrumental assemblies suitable for such special purposes. Use could have been made of instruments already developed for the study of shocks of distant origin, but only under severe limitations. The need for registering in excellent fashion the large numbers of shocks too small to be sensibly perceptible was clear because, since such earthquakes usually affect small areas only, their causal association with particular faults would be easier to fix without ambiguity; and, on account of their numbers, any marked tendency for them to cluster along particular faults or in special areas should prove significant. Consequently, sensitive instruments are required which magnify rapid vibration greatly.

For mechanical registration very large masses would be necessary, which would introduce inertia and bending moments, as well as friction, in very undesirable ways. Optical-photographic recording, which permits the use of instruments of small dimensions and mass, became clearly indicated. The torsion seismometer provided an early and satisfactory solution for recording the

horizontal components of vibratory earth-motion. The vertical component proved less easy to deal with. It was finally found desirable to develop an instrument with galvanometric-optical recording to register this component of the earth motion. Once developed, a similar instrument, having the same characteristics and constants, is found practicable for registering the horizontal components. For very thorough study of the earth motion instruments of still different characteristics have been found useful and important because of the different emphasis placed by their written records upon different aspects of the earth motion. Auxiliary apparatus of this nature has yielded very interesting and important information.

The speeds of propagation of seismic waves are high. With local earthquakes, for which the distances between the origins and the recording stations are comparatively small, relatively large errors are introduced unless the determinations of time—the times of arrival of wave-phases, for example—are very accurate. When such phases are registered sharply it is desirable to determine their times to a tenth of a second or better. This is difficult to accomplish. It requires very uniform rotation of the recording drums at a rate somewhat faster than that commonly in use in the past. For economic reasons, since the recording must be continuous day in and day out, a very fast rate is impracticable. After much development a system has been worked out which is reasonably satisfactory, with further improvement easily possible. The recording drums are rotated by synchronous motors driven by alternating current whose frequency is controlled carefully and kept within very narrow limits, by aid of a vibrating reed or tuning fork. With this system at best

DAMAGE TO MISSION SANTA BARBARA, CALIFORNIA.
SHOCK OF JUNE 29, 1925. (CAMERA TILTED SLIGHTLY OUT OF VERTICAL.)



RUINS OF OLD ADOBE CHURCH,
WITH MODERN BRICK VENEER AND FRAME-SUPPORTED BELFRY, SANTA BARBARA, CALIFORNIA: SHOCK OF JUNE 29, 1925.

we attain the desired accuracy of one tenth of a second, or in rare instances better than this; commonly time determinations are good to two tenths of a second; occasionally they are not better than one fourth of a second; very rarely are they worse than this. Thus when the earth motion produces sharply registered phases, earthquake origins can be located with high accuracy in favorable cases, and very closely in ordinary cases —taking the records of three or more stations into account.

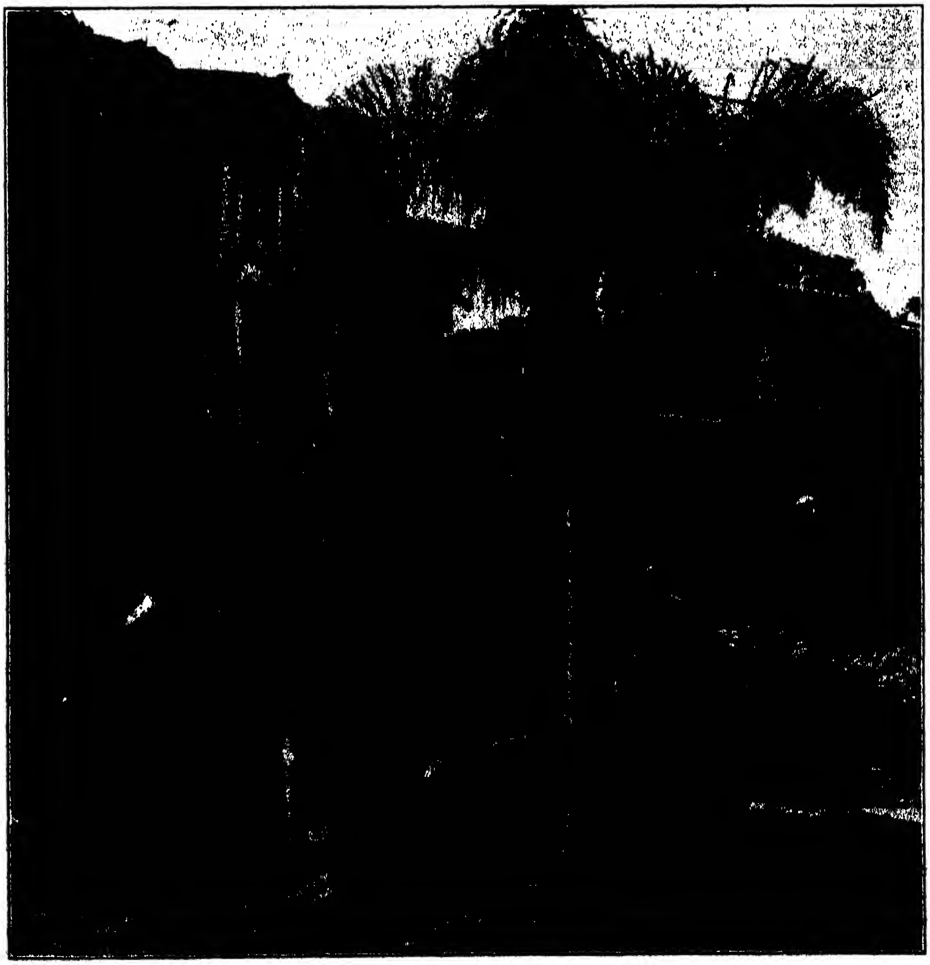
Our stations, equipped uniformly except for additional and auxiliary equipment at the chief station—the Seismological Laboratory—are located at Pasadena, Mount Wilson (at nearly one mile higher elevation), Riverside, La Jolla, Santa Barbara, Haiwee and Tinemaha. For a more completely satisfactory control of the area chosen for study —the region within 500 kilometers, 300 miles of Pasadena—additional stations will be necessary (Fig. 1, p. 337).

The comparison, or correlation, of the time kept by different clocks at the different stations is effected in an ingenious way. At each station there is registered on one recording drum the minute-to-minute time-marks made by the contact-making station clock, written closely parallel with the dot-and-dash signals received from a powerful broadcasting station which is in operation throughout the greater part of the day. Thus, at most times, the clock marks at all stations can be compared directly with the code signals. In this way the clocks are referred to a common relative standard,

since the time errors in registering the code signal are negligible when compared to one tenth of a second.

Although the earth's surface, and its body, must have been shaken at frequent intervals ever since it had a solid crust—the development of seismologic science is of very recent date. Adequate understanding of earthquakes had to wait until there was knowledge of wave-motion in elastic materials and knowledge of geologic mechanics and structure. Earlier views were fanciful or incomplete. In recent years progress has been rapid, but still we know only a little about earthquakes.

We can not pause here to consider the changing status of earthquake knowledge from ancient times onward, giving credit to the very few who mingled sound notions with the confused thought of ancient and medieval days. In the middle of the nineteenth century Mallet and Hopkins cleared the ground and laid foundations upon which Milne and his colleagues, Ewing, Gray and Knott, began to build in the early eighties while they were stationed in Japan. Consider-



THE ARLINGTON HOTEL, SANTA BARBARA, CALIFORNIA.
DAMAGED IN THE SHOCK OF JUNE 29, 1925. (CAMERA TILTED SLIGHTLY OUT OF VERTICAL.)

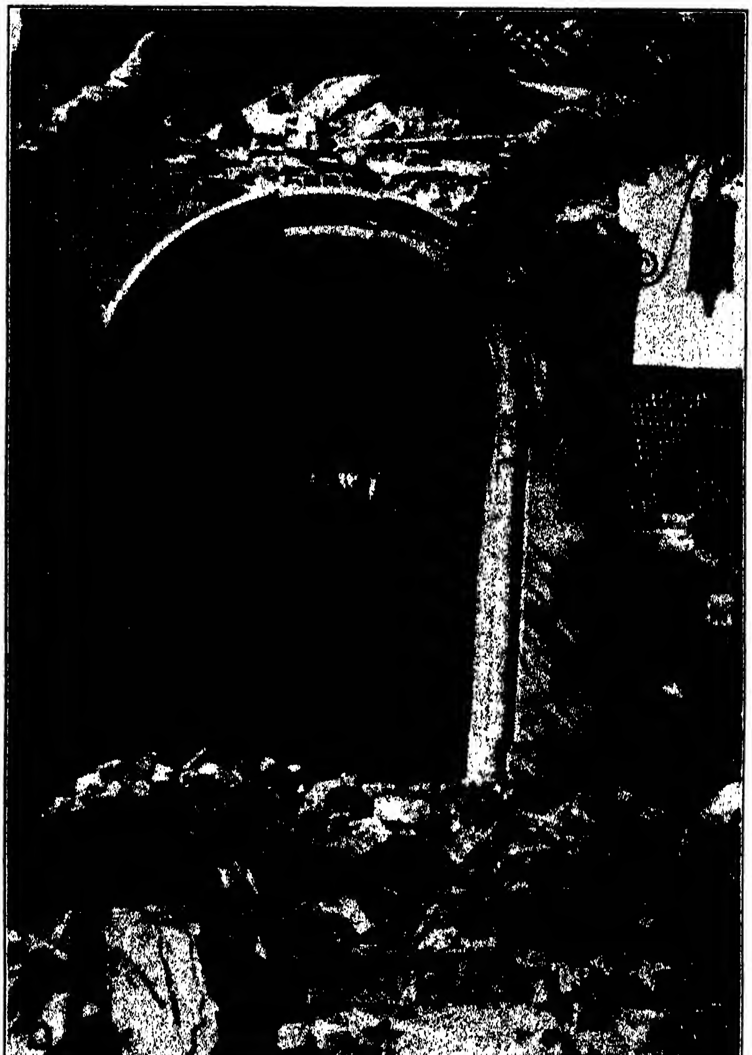
able progress had been made by them and by their Japanese followers, when, in 1900, Oldham published a classic study based upon collected seismograms of the great earthquake which occurred south of the Brahmaputra River in Assam in 1897, and other shocks. In this paper for the first time it was recognized explicitly and, indeed, fairly demonstrated, that the first two chief phases of the seismogram, which we now denominate P and S, were probably waves of longitudinal and transversal vibration, respectively, propagated along similar paths with different speeds so as to arrive at different distances from the origin at intervals characteristic of these distances. The uniform speed of the third conspicuous wave group, now known to be surface waves, was also recognized. This was a great step forward. Glimmerings of these facts and their relationships had, indeed, been glimpsed before, but without clear recognition or any adequate supporting evidence. For the first time the "elongation" of the seismogram and its complication took on important meaning. Oldham's discovery was followed quickly, and practically independently, by the fundamental work on seismographs and seismograms by Emil Wiechert and Karl Zoeppritz and others working at Göttingen.

Practically without exception the records of earthquakes are complicated, both those of distant and those of local origin. After motion begins to be registered, zigzag or sinuous motion of relatively small amplitude, but with many variations in amplitude and period, is registered for a time, followed, usually somewhat abruptly, by similar complicated motion of larger amplitude, which in turn gives way to a third group of waves of complicated nature of still larger amplitude. Neglecting refinements, these are the well-known principal phases, denoted by the letters, P, S and L—the first, or longitudinal waves, the second, or transversal waves, and the long waves, which travel along the surface.

The "elongation" of the seismogram and its complications—what does this mean? In his epoch-making study Oldham was concerned with the records of a very great earthquake, together with those of sundry other very strong shocks, records written at stations at great distances from the places of origin of the disturbances. At such great distances earthquakes which, near their sources, are perceptible to the senses for a few, or several seconds, or sometimes for a minute or two, more or less, write seismographic records which continue registering for minutes and minutes on end up to durations of three or four hours or even more. As stated already, such records are very complicated, with many sudden or gradual changes in the amplitude and period of the recorded motion. More than this, very small shocks, barely perceptible for a brief instant or not perceptible at all—even near their origins, also write records of complicated nature which continue to be registered for many seconds, and even for several minutes in some cases. What is the meaning of this?

Obviously the recognition by Oldham of the three main groups of waves, P, S and L, propagated from the source with different speeds, affords an explanation, at least in part, for the "elongation" and complication of the written record. It was natural at first to attribute the further observed complexity of the record to enduring action at the source, with continued causation of vibratory disturbance. This was suggested by and appeared to find support from the continued perceptibility of motion near the epicenter. Indeed, in part this must be true. But it is not all the truth.

For example, a record written at Pasadena, of a shock produced by a



—*Photo courtesy Portland Cement Association*

ALEXANDER HAMILTON JUNIOR HIGH SCHOOL,
LONG BEACH, CALIFORNIA. SHOWING DAMAGE TO THE EXIT ARCADE OR CORRIDOR: SHOCK OF MARCH 10, 1933.

large commercial blasting operation at Victorville, California, distant nearly 60 miles from the recording station, is spread out over an interval of more than 30 seconds and exhibits at least eleven conspicuous changes in recorded motion which arrived at later and later times, with perhaps still other phases less certainly recognizable (Fig. 2). Now the disturbance which wrote this record was practically instantaneous in nature—the simultaneous detonation by electrical means of a group of explosive charges buried in a body of crystalline limestone immersed in granite of pre-Tertiary (probably pre-Cambrian) age. At the quarry no motion was perceptible to the senses for more than a small fraction of one second. Here, then, we have a definitely demonstrated "elonga-

tion'' and complication of the recorded motion not due to continued perceptible action at the source. In whatever way the successive phases are explained in detail, it is certain that they represent portions of the vibratory energy propagated with different apparent speeds (probably also with different actual speeds)—and since only four essentially different kinds of elastic waves are recognized (two through the body of the earth and two over the surface) it becomes practically sure that different subterranean paths are involved in the transmission of the numerous phases registered.

Thus, the complication of the seismogram almost surely is due in part to the partition of the disturbance, which may be practically instantaneous at its origin, and the distribution of its motion in transit over many paths along which

—*Photo courtesy of Mr. Donald Hillis*

NORTHWEST-SOUTHEAST CRACK

IN GROUND NEAR COMPTON, CALIFORNIA, SHOWING OUTWASH OF SAND WITH INCIPIENT DEVELOPMENT OF ''CRATERLETS'': SHOCK OF MARCH 10, 1933.

the motion is propagated with different speeds, so that different parts of the original motion, leaving the origin at the same time, arrive at the recording station at different times. In part, this is known positively to be a fact, from records like that of the blast.

Hardly less certain is the case with ''identical'' natural earthquakes (Fig. 3). In the recording both of distant and of local earthquakes, many cases have now been found in which records of two or more earthquakes from practically the same source (probably no two sources are ever strictly the same) are essentially identical, with all or nearly all the peculiarities reproduced so faithfully that the records practically can be superposed—except that the amplitudes are different in different cases. With such records it does not appear reasonable to attribute the elongation and complication of the seismogram to *continued causation of identical nature.* Rather, these effects should be attributed to simple causation with a complication of paths and speeds—conditions which would remain essentially the same in such identical cases.

Thus it happens that the simplest explanation for these facts—which is consistent also with all that is now known, and expected—is a separation of the body and of the rocky crust of the earth into parts, or shells, of different material, differing in density and elastic properties, so that vibratory disturbance is propagated with different speeds in each. In detail, of course, the boundaries between the outermost of these shells must be somewhat irregular, occasionally very much so in particular areas. In the large, however, the material may be considered to be arranged in concentric shells.

The first inkling we had of such a condition came, on the grand scale, from the study of distant earthquakes. To be brief, it was early hypothesized that the earth is made up of a rocky crust, an in-

termediate shell or mantle, and a central core. This was the work of Wiechert and Zoeppritz, following quickly after Oldham's epoch-making discovery. A little later it was amplified and refined by Geiger and Gutenberg. The nature of the intermediate shell and of the core has been the subject of much debate, and, indeed, there is still difference of opinion in the interpretation of data bearing upon this. Also other earth shells have been hypothesized. Some of these have been rejected, while others are still under consideration.

When, therefore, in a study of the collected seismograms of a strong earthquake which occurred in the Kulpa Valley in Croatia, Jugoslavia, on October 8, 1909, A. Mohorovičić encountered a definitely twofold aspect of the beginning of the motion as recorded at stations within a limited range of distance from the epicenter, it was natural for him to seek in explanation a horizontal division of the superficial rocky crust into two parts—an upper one (in which the earthquake originated and in which the motion was propagated with a certain speed) and a lower one (in which the speed of propagation was greater). Thus it could happen that motion passing down into the lower medium could there proceed outward and upward again into the upper layer and so reach the recording station in advance of the motion propagated directly in the upper layer with slower speed. However, the motion first to arrive, having been refracted twice, first upon entering the lower layer and again upon reentering the upper layer, would reach the station with less energy and be recorded with smaller amplitude, as the record here reproduced shows (Fig. 4).

This discovery by Mohorovičić was the next great forward step. Out of it has grown a better understanding, both of the seismogram and of the structure of the earth's crust. The principle recognized by Mohorovičić, and extended

—Photo courtesy Mr. H. M. Engle

CONCRETE COLUMN

IN MARTI'S STORE, LONG BEACH, CALIFORNIA, FRACTURED IN THE SHOCK OF MARCH 10, 1933.

by Jeffreys, also has been applied with suitable modifications to work in geophysical prospecting by seismic methods.

As is often the case with such discoveries—in detail the first explanation required simplification to adapt it to use. From the first it was clear to Mohorovičić that, in each layer, the speed of propagation should increase slowly with depth, with a sudden increase upon passing the boundary into the next deeper layer. In his discussion and formulas he endeavored to take account of this slow increase in speed, as well as the sudden increase. This involved recourse to the integral calculus and solution of an integral equation, yielding formulas of elegant form which, however, were somewhat difficult to use in application to practical cases and, in practise, unnecessarily precise.

It remained for the clear insight of Harold Jeffreys to recognize that seismologic data were not yet exact enough to require so rigorous a treatment. He showed that very simple geometric and trigonometric solutions were quite adequate to deal with the data in practically all cases. His simplification has proved an equally important forward step. Numerous succeeding studies have practically demonstrated that the rocky crust is divided into layers or shells, and that the number of such layers and their thicknesses are not everywhere the same. In certain regions there have been recognized (apart from the uppermost irregular sedimentary bodies) an upper "granitic" or "acid" layer, an intermediate "basaltic" or "basic" layer, and a lower "peridotitic" or "ultra-basic" layer. In these the speeds of longitudinal waves have been found to be approximately 5.5 km per sec, 6.3 km per sec and 7.8 km per sec, respectively—and of transversal waves 3.3 km per sec, 3.7 km per sec and 4.3 plus km per sec. In some areas the so-called "granitic" layer is absent, and there is little doubt that further complexity will be found as knowledge grows.

For example, it already appears that in Southern California the crustal structure is more complex, and it is probable that this is the case elsewhere also. In this connection it must be understood that here we approach the present frontier of knowledge in this field. Therefore, conclusions stated at this point may require modification when more is known. With this reservation—as a result of thorough critical analysis of the seismograms of a group of twenty-one of the local earthquakes in Southern California which had been most certainly located and adequately registered prior to the summer of 1931, Dr. Gutenberg has found a probable division of the rocky crust in this region (apart from irregular, superficial, sedimentary basins, sheets and lenses) into four layers and a substratum with speeds for the longitudinal waves of 5.55, 6.05, 6.83, 7.6 and 7.94 km per sec, respectively; with corresponding values for the transversal waves of 3.23, 3.39, 3.66, 4.24, 4.45 km per sec, respectively. The approximate thicknesses of these layers
14 12 4 9
are 0–14, 14–26, 26–30, 30–39, and greater than 39 kilometers. These find-

—*Photo courtesy of Portland Cement Association*

THE JEFFERSON JUNIOR HIGH SCHOOL

LONG BEACH, CALIFORNIA; A PORTION OF THE BUILDING WAS IN A STATE OF TOTAL COLLAPSE IN THE SHOCK OF MARCH 10, 1933.

—*Photo courtesy of Portland Cement Association*

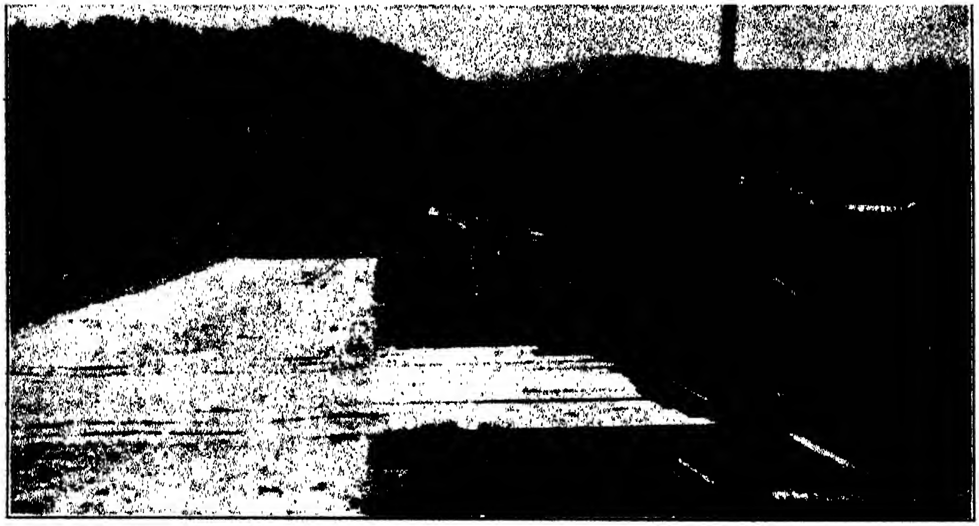
CENTRAL SCHOOL, HUNTINGTON BEACH, CALIFORNIA.

BADLY CRACKED WALLS, ORNAMENTAL PILLARS DESTROYED, DÉBRIS AT ENTRANCE: SHOCK OF MARCH 10, 1933.

ings will be the subject of repeated tests as time goes forward.

Theoretically, an elastic wave, upon encountering the boundary between two media of different elastic moduli and different densities, undergoes a transformation into four elastic waves with division or partition of the original energy—two waves reflected at the boundary, one vibrating longitudinally and one transversally; and two waves refracted through the boundary, again one a longitudinal and one a transversal wave. However, under certain conditions some of these vanish, either completely or practically. In spite of this it is obvious that if either the earth as a whole or its superficial rocky crust is divided into two or three or more shells or layers of significantly different nature, reflected and refracted waves must arise, some or all of which will be propagated to the recording stations and there registered. The number of phases thus recorded, and the amplitudes and periods of the motion, will vary with the distance of the stations from the origin and other conditions. In this way the seismogram is still further complicated and in many instances made more difficult to interpret. Thus the earth, and its crust, may be thought of as something resembling in a crude way a complicated prism or set of prisms or lenses, reflecting, refracting, diffracting and dispersing the undulatory energy which spreads outward from the earthquake origin.

Further obstacles stand in the way of straightforward and rapid progress because the region of the shock origin may be, and probably frequently is, multiple in nature or of extended dimensions—thus, in detail, giving rise to different sets of waves independent, in a minute way, in time and place of causation. As a result of all this, the interpretation and measurement of the seismogram—



—*Courtesy of U. S. Geological Survey*

ROAD BROKEN BY FAULT MOVEMENT
NEAR POINT REYES STATION: SHOCK OF APRIL 18, 1906.

simple and straightforward in theory—at times becomes very complex and sometimes well-nigh insoluble, with the appearance of wave-arrivals, or phases, for which no explanation can be found readily or surely. Fortunately, such extreme complexity is not common enough to halt progress or retard it greatly.

Recognition of definite direct, refracted, reflected and diffracted wave-arrivals (usually differing in amplitude and period)—marking phases of the seismogram—later and later, and more and more widely separated in time, the farther the recording station is from the origin, has made possible the construction of tables and curves or curve-families, showing the times of arrival at different distances or the transmission-times, transit-times or travel-times of these various waves, from which useful and often very accurate estimates of the distance of the shock-origin from the station can be derived.

For distant shocks the first significant diagram of this kind was that published by Oldham (Fig. 5), followed soon after by Milne and a little later by the far more extended and accurate curves and tables of Wiechert and Zoeppritz, which form the basis of all later work. Important contributions to the improvement and refinement of such tables and curves have been made by many workers, prominent among whom are Mohorovičić, Turner, Macelwane, Byerly, Hodgson, Wadati and especially Gutenberg (Fig. 6) and Jeffreys.

A very late curve-diagram of transmission-time for local shocks is that resulting from Gutenberg's study of shocks in Southern California (Fig. 7). It will be clear from mere inspection of this that experience and care is required in the practical utilization of such a diagram in determining the distance of origin of a shock from a given station. As experience grows, this curve-diagram almost surely will be modified. Whether it will be simplified or grow more complex—but more certain—we can not foresee.

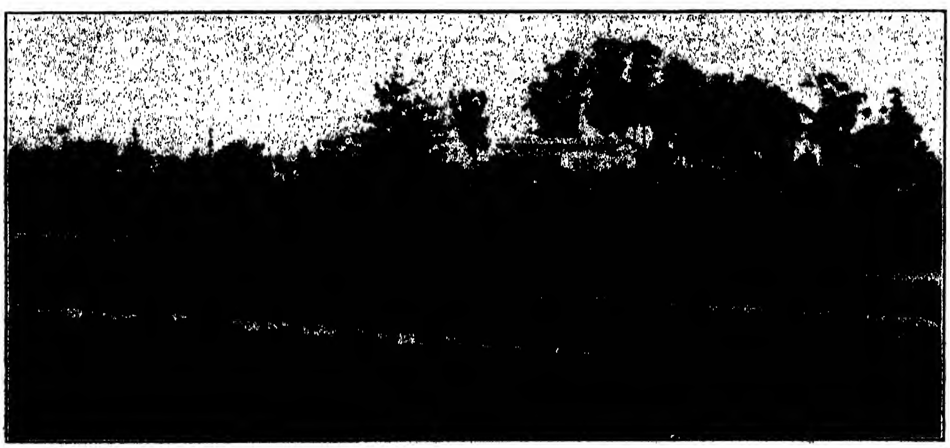
From the first, one of the chief objects in our research program has been determination of the geographic location of the epicenters of as many as

possible of the small earthquakes which occur in the region within 300 miles of Pasadena, approximately, and study of the relationships which appear between these and the geologic faults, structures and activity in the same region.

Under very favorable circumstances the epicenters can be located within one or two kilometers; and in a large percentage of cases within 5 to 10 kilometers—but in practically every case the location is an approximation, since the slightly curved, or broken, path followed by the vibratory motion in passing from the region of origin to the recording station can be estimated only approximately, not precisely known. For this reason also, except for possible rare cases of unusually favorable nature, until stations are far more numerous and closely spaced, the depth of the region of origin will be uncertain within limits which may well be different in different cases. Such uncertainty as to depth also affects, sometimes more, sometimes less, the accuracy of the location of the epicenter.

One way of placing the epicenter is that known as the S-P method—in which the time-interval between the arrival of the transversal or S-waves and the longitudinal or P-waves is measured and the distance from the origin to the recording station is approximated by multiplying the time-interval by a number determined empirically by experience or calculated from theory. The rationale of this method is simple—the P-waves and the S-waves in passing from the origin to the stations traverse similar paths at different speeds so that their times of arrival will differ by an amount corresponding to—mathematically expressed, a function of—the distance. Given three or more origin-distances determined in this way, circular arcs drawn on a map, using the stations as centers and the origin-distances as radii, will intersect in a small area in or near which the epicenter must lie. This affords an approximation only, since the paths traversed by the P and S waves may not be quite identical (although they can not differ by any very significant amount) and especially, since it often is difficult to determine the time of onset of the S-waves with as high precision as in the case of the P-waves.

A better procedure (which, fundamentally, is the same method) yields the approximate epicentral distance of the station by the careful comparison of the



—*Photo courtesy Portland Cement Association*

BUCKLING OF CONCRETE PAVEMENT

ON ATLANTIC STREET, RUNNING NORTH AND SOUTH, NORTH OF SIGNAL HILL, NORTH OF LONG BEACH, CALIFORNIA: SHOCK OF MARCH 10, 1933.

—Photo courtesy Portland Cement Association

BUILDING AT LONG BEACH, CALIFORNIA,
OCCUPIED BY CONTINENTAL BAKING COMPANY, WHICH COLLAPSED IN THE SHOCK OF MARCH 10, 1933.

phases shown on the seismogram with tables, or curves, of transmission-times for several or many phases. In this way the estimate is not based upon the single time-interval, S-P. Circular arcs are drawn as in the case just discussed. With this method, within small limits, the same origin-time should be indicated at all stations, as read directly from the curves.

When the data will permit, a still more accurate method consists in the determination of the arrival-times of definitely identified phases at three or

—Photo courtesy Portland Cement Association

TOTAL COLLAPSE OF BUILDING AT COMPTON, CALIFORNIA:
ANGELES ABBEY MAUSOLEUM, VIRTUALLY UNDAMAGED, IN BACKGROUND; NOTE STREET LIGHT WITH GLOBES INTACT, BUT WITH ONE TOP BROKEN: SHOCK OF MARCH 10, 1933.

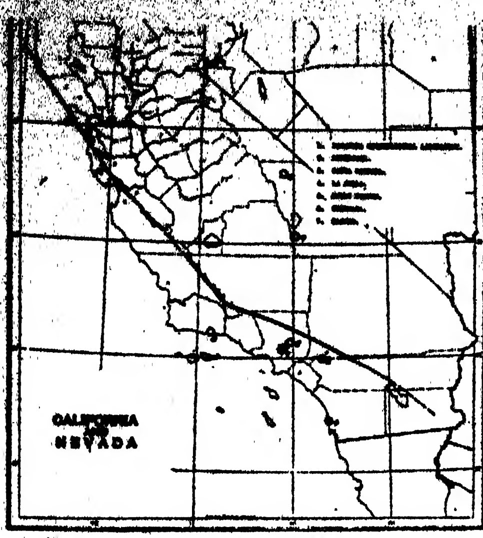
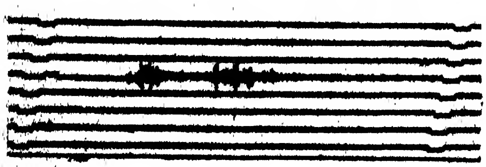


FIG. 1. LOCATION OF STATIONS IN SOUTHERN CALIFORNIA

THIS MAP ALSO SHOWS THE COURSE OF THE SAN ANDREAS FAULT, WITH THE SEGMENTS ON WHICH SURFACE FRACTURE OCCURRED IN 1906, AND IN 1857, EMPHASIZED ON HEAVY SOLID LINES.



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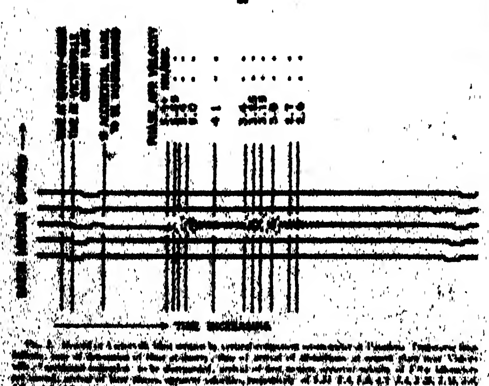
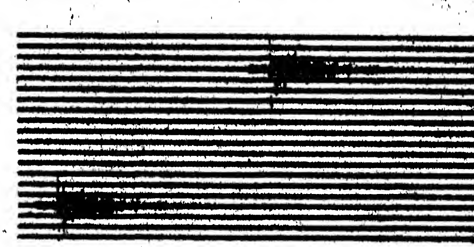


b

FIG. 2. RECORD AT PASADENA OF BLAST NEAR VICTORVILLE

DISTANCE NEARLY 80 MILES. (a) FROM ORIGINAL SEISMOGRAM; (b) SHOWING PHASES MARKED.

more stations. The difference between the times of arrival of the *same phase* at two stations, multiplied by the speed of propagation of the motion of the phase in question, gives the difference in distance from the origin of the two stations involved. Knowledge of this difference in distance permits the drawing on a map of a hyperbola or hyperbolic arc, which is the locus of all points more distant from one station than from the other by the amount thus determined (according to the phases used, this hyperbola will be the surface-trace of a hyperboloid of revolution or of a hyper-



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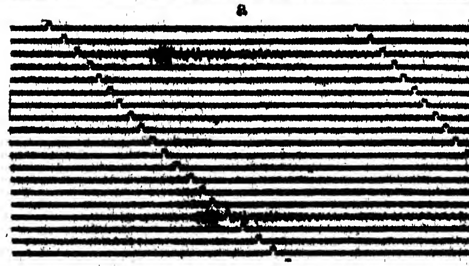


b

FIG. 3. "IDENTICAL" SHOCKS

FROM PRACTICALLY THE SAME SOURCE AT DIFFERENT TIMES. THE SAME TWO SHOCKS: (a) REGISTERED AT HAIWEE, $\Delta = 40$ KM APPROX.; (b) REGISTERED AT TINEMAHA, $\Delta = 150$ KM APPROX.

bolic cylinder). The intersection of two or more such hyperbolas will determine the epicenter within limits which depend upon the obliquity of the intersections, as is also the case with circular arcs. In some instances, with both circular and hyperbolic arcs, intersections at depth will help to determine the depth of origin, but frequently the range thus indicated is too great to be useful. Implicitly, this method also as-

sumes that the origin-time is the same at all stations used. This affords a check upon the accuracy of the determination.

Once the epicenter has been found approximately, the accuracy of its location can be improved—when the arrival-times of the P-phase (or of some other *surely* identified phase) are known very precisely—by successive approximations, in which the distances are calculated and the point chosen successively adjusted until a position is found for the epicenter which gives the same origin-time at all the stations used within the limits of error of time- and distance-determination which inhere in the observations and the methods of calculation. In the present state of knowledge this is the best that can be done.

Results of this, as they have been obtained, have been shown on maps exhibited here in the Institution Building for several years past and again this year. Thus far, it appears to be demonstrated by the clustering of earthquake origins along their courses that several of the geologic fault zones are active sources of shocks at the present time. Some, like the local segment of the San Andreas fault, known indubitably to be active sources, have been almost quiet during the last few years. Also many well-determined places of origin are not

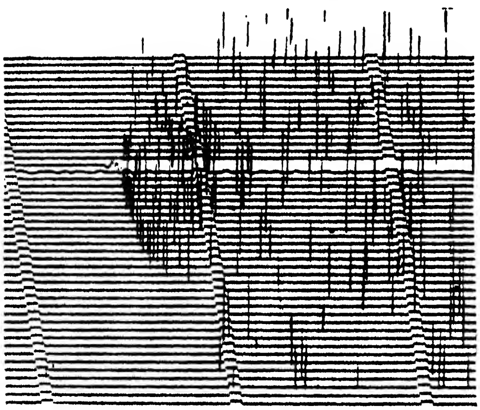
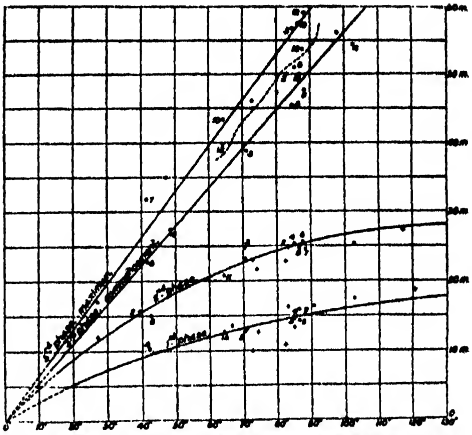


FIG. 4. LOCAL EARTHQUAKE RECORD SHOWING TWOFOLD ASPECT OF THE BEGINNING.



Time curves of the three phases of earthquake motion recognisable in distant records.

FIG. 5. OLDHAM'S ORIGINAL TRANSMISSION-TIME CURVES PUBLISHED IN 1900.

associated with any faults known or suspected at the surface. To account for such relations we have several hypotheses in mind, which will require much further testing before safe conclusions can be drawn.

An interesting and important outcome of our work is the development of a *scale of magnitudes* for earthquakes. This achievement is new. Such a scale differs fundamentally from a *scale of earthquake intensity*. A measure of the intensity of an earthquake is, more or less approximately, a measure of the strength or destructiveness or energy of an earthquake at a particular place. Consequently, the *intensity* of an earthquake varies from place to place over the area affected. Of course, the *maximum intensity* in the central region to some extent is directly related to the greatness of the shock, but the local value of the intensity in every case varies from place to place. The magnitude, on the other hand, is a measure of the size of the shock as a whole.

As closely as is practicable all our short-period torsion seismometers are constructed alike. Except as manufacturing difficulties introduce small dif-

ferences, they all have the same dimensions, periods, damping, magnification and so on. Each of our stations has two of these instruments in operation. Theoretically, a given shock will have the same effect upon all these, in general, except for those differences in energy and amplitude, directly due to different distances of the stations from the origin of shaking, which arise from the spreading of the energy and its absorption. In practise—speaking very exactly—the instruments do differ somewhat in behavior because it is impossible to make them all very precisely alike, and, further, the natural ground or rock at the various stations is not the same.

In some places the seismic motion consistently is registered with larger amplitudes, relatively, than at other places,

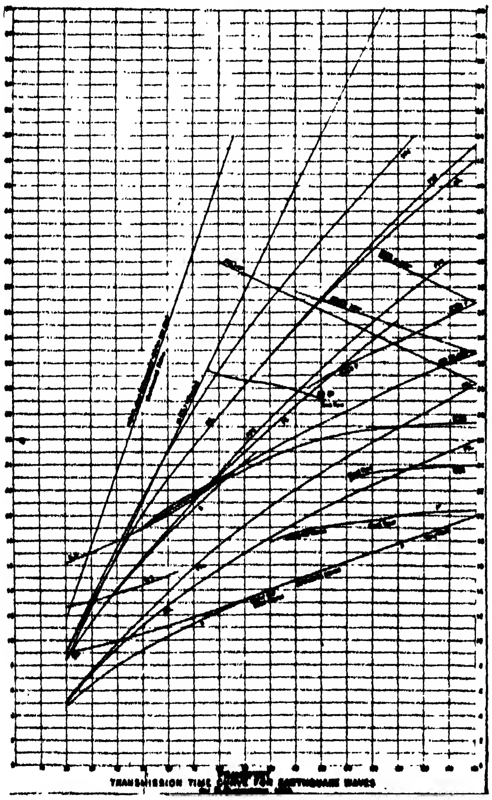
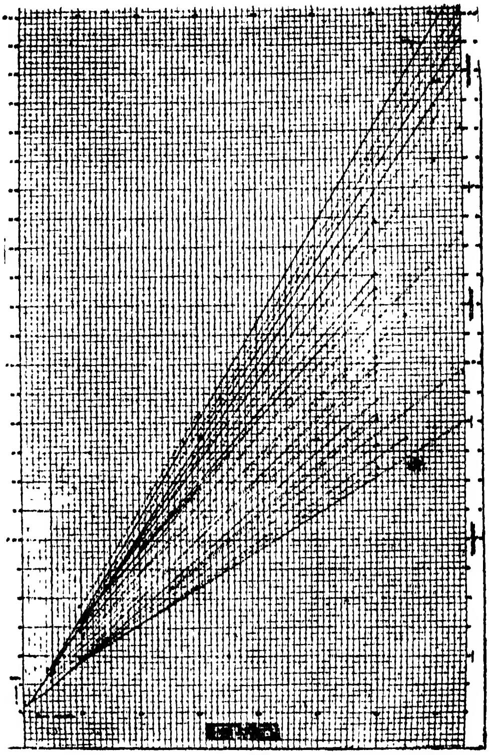


FIG. 6. TRANSMISSION-TIME CURVES AFTER GUTENBERG



—*B. Gutenberg*

FIG. 7. TRANSMISSION-TIME CURVES FOR LOCAL EARTHQUAKES IN SOUTHERN CALIFORNIA

due perhaps to instrumental differences but more probably to differences in foundation ground. In spite of these factors, which render high precision impossible, it is found that comparison of the amplitudes registered at well-determined epicentral distances, with the amplitudes, at the same distances, of a "standard" shock, which have been worked out by successive approximations from sufficient data, yields a value for shock magnitude which comes out the same at all places, within limits of error which are reasonable, even though rather large.

In actual experience the range of amplitudes is so great that the scale adopted is a logarithmic one in which only the characteristic term of the logarithm need be considered. Taking the

small standard shock as the unit, with characteristic logarithm 0 (10^0) 16 degrees of magnitude corresponding to actually observed shocks have been distinguished and recognized already, taking whole numbers and half-numbers from 0 to 7.5, inclusive. Almost surely the greatest earthquakes are of magnitudes still higher than this. The scale is a scale of *registered* amplitude (with essentially identical equipment) in which the defining amplitude for a shock of a given magnitude is 10 times that for the next lower whole number of the scale and 1/10 that for the next higher whole number. Since the energy of the shock varies with the square of the amplitude it follows that the energy of a shock of magnitude 7.5 is 10^{15} times that of the unit standard shock of magnitude 0. The standard shock has been chosen so that it would have a registered amplitude with our torsion seismometric equipment of one micron at the epicentral distance of 100 kilometers with correspondingly greater and less amplitudes at less and greater distances.

On this scale of magnitudes the Long Beach shock of March 10, 1933, works out to be 6, and that of the shock of December 20, 1932, in Nevada, to be 7.5. At this late date the magnitude of the 1906 shock in Central California can only be estimated approximately, but, by comparison with the Nevada shock, it must have been 7.5 at least and probably higher. On this somewhat uncertain basis the energy of the 1906 shock must have been at least 1,000 times that of the Long Beach shock, and almost surely more. As experience with this scale is extended, it may prove possible to arrive at a more positive comparison between these earthquakes, but that given here is probably of the right order.

Within the past five years it has been shown definitely that some earthquakes originate at depths below the earth's surface as great as 400, 500, 600 and more kilometers, in round numbers. A majority of earthquakes, however—a very great majority, if small local shocks are included—originate at small depths, less than 20 kilometers in large part. We do not yet know the cause of deep-focus earthquakes nor whether shocks originate freely at all depths down to the maximum.

Recognition of deep-focus shocks was first clearly voiced by Oldham, but the data at his disposal were not adequate to establish his view convincingly, and he himself pointed out that no adequate mechanism for causing them was known, though he presented suggestions for consideration. Consequently, though his hypothesis was by no means lost sight of among geologists, it did not find any wide acceptance among instrumental seismologists, notwithstanding some support given it in a study published by Pilgrim shortly before the Great War, for the seismographic criteria had not then been clearly recognized. Events have proved Oldham right in his general view, but he reached corollary conclusions which do not seem to find convincing support.

After the death of Milne, Turner, upon taking up the work of the assembly and digest of earthquake reports which is published in the International Seismological Summary, began to find peculiarities in the times of arrival of phases on the seismograms in certain cases which, *if they were correctly interpreted and measured by the reporters,* would point to origins at great depth for the shocks in question. However, he also found other cases in which the data reported to him would point to "high focus," some of these apparently indicating origins above the surface of the earth. This latter absurdity, together with general knowledge among working seismologists that phases frequently were wrongly interpreted by some of the

less experienced workers, kept this view of Turner's from making headway among seismologists generally, since it was known that he did not have direct access to the actual seismograms, but necessarily was restricted to the interpretations and measurements made and reported by others. Other early divergent views of his, based upon these station reports, later brought into accord with general knowledge, plainly rested upon imperfect data. So, while it is now known that Turner was right in many instances of deep-focus shocks, in many others he was led to wrong conclusions by inaccurate information. His view did not prevail at first, nor until later work brought support of it.

Thus it was left for Wadati, in a paper published in 1928, to establish the fact of the occurrence of deep-focus earthquakes, by methods and data satisfactory alike—after verification—to instrumental seismologists and to students of earthquakes who follow older, field methods. Subsequently, Scrase and others have confirmed the occurrence of such shocks and extended our knowledge of their seismographic phases and transmission-times. Among other things such shocks are characterized chiefly by the registration of early reflected phases, thrown back from the surface of the earth—and the virtual absence of large surface waves, a criterion pointed out by Lamb on theoretical grounds much earlier.

It happens that our own vertical-component instruments and some of our special auxiliary apparatus are unusually well suited for registering these shocks recognizably, and since the establishment of their reality and the discovery of the criteria which distinguish them, we have found that their occurrence is by no means a rarity, though they are fewer in number than normal shocks. In this connection it is interesting that Zoeppritz more than 20 years ago recognized a difference between the records of these and of normal distant shocks but did not hit upon the explanation. The records of such shocks were long considered to be the incomplete registration of very distant earthquakes. Thus far the origins of these shocks appear to have been limited narrowly to the Asiatic coastal region and nearby mainland, with a few located in Western South America, and fewer still in Central Asia.

Although in our research program emphasis is laid primarily upon investigation of the local earthquakes which originate in the Southern California province, at the Seismological Laboratory in Pasadena we operate some routine instruments and some auxiliary apparatus especially adapted for the registration of distant shocks. We thus contribute our share to the data necessary for progress in this part of the field. Also we are engaged in a systematic detailed study of the records of three major distant earthquakes borrowed from a great number of the stations which make up the world-wide network. The experience gained from such studies is essential for the investigation of such larger shocks as may originate in or near our own province.

An interesting and important field has been opened up by promising experiments which have been made with explosives and field seismographic equipment like that used in seismic prospecting—with a view to determining, by the registration of reflected and refracted waves, the depth and attitude of strata or rock bodies within the superficial crust competent to produce such reflections and refractions. For the uppermost part of the crust excellent results have been obtained, but as yet only uncertain findings have resulted, for the most part, from the lower part.

As stated in the beginning, our work in a sense is a sequel of investigations

stimulated by the occurrence of the 1906 shock in Central California.

One important outcome of the detailed study of that shock was the great emphasis which it laid upon the fact—previously recognized on many occasions—that, other things being equal, the destructiveness of an earthquake within the area near to the origin is related in a very intimate way to the nature of the ground at the surface—great apparent intensity or violence (as measured by destructive effect) being manifested upon "made" ground and loose natural alluvium, *especially when thoroughly charged with water*, with comparatively slight apparent intensity upon firm rocky ground at the same or comparable distances from the source of shaking. Intermediate effects were exhibited on ground of intermediate quality.

Experience in later shocks has abundantly confirmed this finding—in an especially striking way in the recent Long Beach earthquake for which the area outstandingly marked by damage in unsuitably designed structures corresponds almost exactly with that portion of the deeply alluviated Los Angeles plain where ground water reaches nearly or quite to the surface. However, it may be noted in passing that structures suitably designed and well built withstood the shaking well even on such ground, since the shaking only attained minor destructive power on this occasion.

Though the relation was less striking, similar findings prevailed in the cases of the Santa Monica earthquake of August 30, 1930, the Whittier shock of July 8, 1929, and the Santa Barbara shock of June 29, 1925—as well as others more remote. The outstanding association of greater apparent violence with loose wet ground has led many, including some trained geologists who are not specialists in earthquake study, to seek the origins of shaking in places aside from those indicated by instrumental findings. It may be well, therefore, to emphasize the fact that in two instances we have exceptionally well-determined positions for the shock origins, in both of which the field data tend to be misleading to students of small experience, or persons who do not examine all the facts critically.

In both the Santa Monica shock of August 30, 1930, and the Long Beach shock of March 10, 1933, the place of origin happened to be situated almost exactly equidistant from two of our stations, a fact which severely limited its geographic position. In both cases the data of all the stations indicated epicentral areas of very small dimensions consistent with these conditions of equidistance. It seems probable that we know the positions of the origins of these shocks within one or two kilometers. If the uncertainty is larger than this, it is still very small.

Notwithstanding this, in both these cases, and in others also—foundation ground and quality of building aside for the moment—the greatest apparent intensity was manifested not immediately at the epicenter but a little distance away from it. This observation, together with other circumstances, leads to the tentative conclusion that destructiveness and the apparent intensity based upon it are closely associated with waves at the surface, possibly elastic waves, possibly quasi-gravitational waves, possibly both in turn, and that these, as indeed theory suggests, do not have their genesis or their maximum development at the epicenter but at a little distance away from it, either symmetrically around it or otherwise, according to the specific nature and action of the causative mechanism. The distribution of effects also sometimes suggests analogies to an interference pattern due possibly to different constructive and destructive combination of waves at different places. Proof

of this suggestion is exceedingly difficult.

There remains for further brief consideration the Long Beach earthquake of March 10, 1933. It is, of course, a fact that this shock caused by far the greatest loss of life, the most numerous injuries to persons and the largest financial loss and destruction of property ever occasioned by earthquake in Southern California. Notwithstanding this, the Long Beach shock was by no means the greatest earthquake, in point of magnitude, nor the strongest one, in point of intensity, which has visited the same immediate district during the time, less than two centuries, since white men came to occupy it. Both in magnitude and in intensity the shock was comparable with that which laid Santa Barbara low in 1925—perhaps a little greater, perhaps a little less. Nevertheless, it was, probably, the most considerable shock to occur in the same immediate neighborhood in nearly eighty years. This long interval of relative seismic immunity, combined with a gentle climate (no hurricanes, no tornadoes of any magnitude, hardly ever hard gales, rare floods, no heavy snows), a wide plain of loose, deep, water-soaked alluvium and low hills of uncemented sediments and a phenomenally rapid influx of population in the last two decades, resulted in numerous considerable towns, villages and cities—assemblages of houses, shops, industrial plants and other works of construction ill-designed and badly built to withstand any severe or unusual stresses. This was true especially of business buildings and unfortunately of schools, churches and other public and semi-public places of assembly. Consequently, when fairly hard shaking came again the result fell short of a great disaster only by good fortune—a good fortune which has now been repeated several times in California in connection with nearly all the greater shocks which have occurred there.

By every criterion known, the shock of March 10, 1933, fell short of being a great earthquake—duration, intensity of shaking, size of the area in which damage occurred, size of the area of perceptibility and the distance to which it was well recorded by seismographs. It was, however, a moderately large, fairly strong local shock. Its characteristic maximum intensity was VIII of the 1931 Modified Mercalli scale, VIII plus to IX of the Rossi-Forel scale so long in use. There were a few small scattered places where intensity IX of the 1931 scale may have prevailed. The damage, injury and loss of life were due in overwhelming measure to bad or wretched building, or to bad or wretched natural or artificial foundation ground, and to both in combination.

Nevertheless, we must go back to 1857 or 1855, and perhaps to 1812, for a shock of comparable strength affecting the same area.

The shock of 1857, originating in slipping along the south central to southern segment of the San Andreas fault (Fig. 1) for a distance of 200 miles or more, was a great earthquake. Probably it somewhat exceeded in magnitude the 1906 shock in Central California, but *its intensity in the Los Angeles plain* may not have risen so high as that in March, 1933.

The shock of 1855 was strong in the same immediate region. "Almost every structure in Los Angeles was damaged, and some of the walls were left with large cracks. Near San Gabriel . . . (an) adobe . . . was wrecked, notwithstanding that it had walls four feet thick with great beams of lumber . . ." Changed conditions make it impossible to compare this shock with that of March, 1933, more closely.

There seems little doubt, however, that the shocks in the autumn of 1812 were both greater and stronger than that of March 10, 1933; and the probability is very strong that the shock of

July, 1769, was also stronger in the Los Angeles plain than the shock of the year 1933.

Within narrow limits the source of the March, 1933, shock was three and one-half miles off-shore southwest of Newport Beach in the course of the Inglewood fault zone projected southeastward. Since moderately hard shaking continued for 10 to 15 seconds, it is probable that the region of origin underwent some enlargement during the interval. But all investigations carried through thus far indicate that such development was not extensive.

Aftershocks were very numerous, instrumental registration being continuous for many hours with the more sensitive apparatus at Pasadena some fifty miles away from the source. The maximum registered amplitudes of the largest aftershocks were less than 4 per cent. of the maximum registered amplitude of the chief shock on the strong-motion records at Pasadena. For many of the aftershocks, especially those which occurred soon after the main shocks, the places of origin were very close to that of the main shock. Others, however, especially later ones, were located at various distances away from the original source, up to 15 or 20 miles, both to the northwest and to the southeast. Our study of these is still in progress. Conclusions based on our present knowledge of these would be premature.

While aftershocks usually fall off in number and size rather rapidly, depending somewhat on the size of the chief shock, it is, of course, difficult to determine when their course is completely run until the lapse of time has been sufficient to develop the picture fully.

Consequently, it is difficult to state with certainty whether the sharp shock of October 2, 1933, should be regarded as an aftershock or as an independent earthquake. In any case it was stronger than any of the sure aftershocks which followed the shock in March, but only a little stronger than the larger immediate aftershocks. Its origin was located some 17 miles to the northwest of that on March 10—near the southeast end of Signal Hill, also in the zone of the Inglewood fault.

It is otherwise with the smaller shock of October 24, 1933, which, nevertheless, was a sharp earthquake. This shock originated about one-half mile north of the village of Downey—very probably on that fault which was the source of the barely destructive Whittier earthquake in July, 1929, at a point further west than the earlier shock.

This brings the record up to date, as nearly as possible, and gives, I hope, a reasonably clear picture of the work we are doing and of its trends and purposes in the field of science and for human welfare.

YOUR NOSE KNOWS[1]

By Dr. MARSTON T. BOGERT

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No other sense is so marvelously acute as that of smell, so widely and extensively connected with other brain centers, or so potent in awakening our memories and our emotions.

The amount of an odorous substance necessary to produce the sensation of smell is incredibly minute. Camphor is said to be detected in a dilution of one part in four hundred thousand, musk one in eight million, and vanillin one in ten million. Valentin[2] found that one twenty-thousandth of a milligram of otto of rose was all that was required. Fischer and Penzoldt[3] determined that one 460-millionth of a milligram of the rotten egg odor of ethyl mercaptan was the approximate minimum amount which, coming into contact with the olfactory nerves, could be immediately recognized by them, which is about 250 times less than the minimum amount of sodium which can be detected by the spectroscope, according to the experiments of Kirchoff and Bunsen.[4]

The pleasant odor of the soil was ascribed by Berthelot, the distinguished French chemist, to traces of an unidentified camphoraceous body of so powerful a fragrance that even a trillionth of a milligram gave a clearly perceptible aroma.

It is also one of the senses particularly susceptible to "adaptation," *i.e.*, a diminution or cessation of the sensation in spite of the continuance of the stimulus, a phenomenon probably akin to fatigue. Both individuals and odors show widely divergent behavior in this respect. Some odors quickly fatigue or benumb the sense of smell in nearly all persons; whereas, with other smells, only a few individuals will gradually lose their ability to detect them while remaining in the same atmosphere. This is the great danger of hydrogen sulfide, for it quickly paralyzes the sense of smell and the victim may not be aware that he is being poisoned until he suddenly falls to the floor unconscious.

Some people may be indifferent to music, but those unaffected by odors are rare indeed. A breath of perfume brings instantly before our vision past scenes with all their pain or pleasure. From certain odors we recoil instinctively, not because they are intrinsically unpleasant, but because of the associations they recall; while others, perhaps unattractive to our fellows, possess a peculiar fascination for us. The recognition of a perfume is instantaneous, as is the picture it conjures up.

Goethe visited Schiller one day and, not finding him at home, waited in his study, where he sat down to a table and began to write a few notes. Gradually he felt increasingly sick and faint. Frau Schiller inquired the cause of this sudden illness, and the poet said he thought that it was due to a peculiar odor in the room. Whereupon she opened a drawer full of decayed apples and took them away. Afterwards she explained that for some mysterious reason the odor of rotten apples stimulated Schiller and he couldn't do his best work without it. So that what caused a profound constitutional disturbance with Goethe was a beneficial stimulant to Schiller.

Oliver Wendell Holmes wrote that "memories, imagination, old sentiments

[1] An address presented at the meeting of the American Chemical Society, St. Petersburg, Florida, on March 27, 1934.

[2] *Lehrb. d. Physiol.*, II, 2, 279, 1848.

[3] *Ann.*, 239, 131, 1887.

[4] *Pogg. Ann.*, 110, 168.

and associations are more readily reached through the sense of smell than by almost any other channel,'' an opinion in which Kipling concurs when he says "Smells are surer than sights or sounds to make the heartstrings crack.''

Holmes also has written:

> Perhaps the herb everlasting, the fragrant immortelle of our autumn fields, has the most suggestive odor to me of all those that set me dreaming. I can hardly describe the strange thoughts and emotions that come to me as I inhale the aroma of the pale dry rustling flowers. A something it has of sepulchral spicory, as if it had been brought from the cave of some great pyramid, where it had lain on the breast of a mummified Pharaoh. Something too of immortality in the sad, faint sweetness lingering so long in its lifeless petals. Yet this does not tell why it fills my eyes with tears and carries me in blissful thought to the banks of asphodel, that border the river of life.

Or, to quote Bret Harte:

> But the smell of that subtle, sad perfume,
> As the spiced embalmings, they say, outlast
> The mummy laid in his rocky tomb,
> Awakens my buried past.
>
> And I think of the passion that shook my youth,
> Of its aimless loves and its idle pains,
> And am thankful now for the certain truth
> That only the sweet remains.

The literature of all civilized countries is replete with similar illustrations.

The allure and fascination of perfumes have been more potent factors in the rise and fall of empires than most of us realize. Anthony sacrificed his empire and his life to the seductive aromatic Cleopatra. The Medicis were famous for their perfumes and infamous for the way in which they used them to mask the deadly poisons with which they eliminated their enemies. One of the carefully guarded secrets of the British royal family is said to be the formula of a specially prepared perfume with which Buckingham Palace is sprayed for the Court presentations attended by distinguished men and women from all parts of the world. This perfume is believed to be entirely original and suggests a tropical flower garden. It has been used since the time of Queen Victoria's first Court, and its composition is said to be known only to the King and Queen, in addition to the manufacturers themselves.

That the English Parliament of 160 years ago must have been seriously concerned about the use of perfumes seems to be indicated by the law which they enacted during the reign of George III, in 1774, the same year in which Priestley discovered oxygen and that the First Continental Congress assembled in Philadelphia. This law stated that:

> All women, of whatever age, rank, profession or degree, whether virgins, maids or widows, that shall from and after this act impose upon, seduce and betray into matrimony any of His Majesty's subjects by the use of scents, paints, cosmetics, washes, artificial teeth, false hair, Spanish wool (impregnated with carmine and used to this day as a rouge), iron stays, hoops, high-heeled shoes or bolstered hips, shall incur the penalty of the law now in force against witchcraft and like misdemeanors, and that the marriage, upon conviction, shall stand null and void.

How much we depend upon the nose to distinguish between healthy and diseased individuals, between sanitary and unsanitary conditions! How frequently it warns us against pollution of air, food or drink, against pestilence, hazards and dangers of all kinds! And yet we repay this debt to the sense of smell with quite general indifference and scorn. When the nose is powerless to help, as in the case of such deadly gases as carbon monoxide, our life is in immediate jeopardy, as witness the recent asphyxiation of nine students in a Dartmouth fraternity house. There is a real danger that, through long-continued disuse and neglect, we may some day lose our sense of smell entirely.

Plumbers to-day still use occasionally the time-honored method of locating leaks in the plumbing by introducing oil of peppermint and then sniffing along the pipes.

The chlorophenols have such powerful and distinctive odors, of rank carbolic type, that they have been employed successfully to trace stream pollution. Professor Holleman of Amsterdam, when he was working upon such products several years ago, told me that he happened to be shopping one day in a busy part of the city, when he was suddenly startled by the recognition of this familiar chlorophenol odor, and looking up the street to windward, saw, many blocks away, his assistant coming toward him, who proved to be the undoubted source of the odor.

The reason why the sense of smell in the case of animals was the first of the special senses to be extensively developed was probably because they, especially the quadrupeds, depend more upon scent than upon sight to warn them of impending danger.

The fetid excretions of many insects and other animals, when not of sexual significance, are probably intended for defensive purposes and, so far at least as our friend the skunk is concerned, I think that we will all agree that the defense is an effective one.

Man has occasionally made use of the odor sense of animals for his own protection. An interesting case was cited not very long ago in which an intelligent plumber was called to locate the source of an evil smell in a London store. Examination of the room failed to disclose the location of this smell and a study of the plans of the building failed to show any plumbing work in the room. Later, as the result of additional complaints that the foul odor was making many of the women employees so ill that they could not stay in the store, a further examination of the room was made with similar lack of success in locating its cause. The plumber then had a bright idea and went to a neighboring butcher shop, where he caught a bottle full of blow-flies, knowing that they are always attracted by such odors. These were released in the troublesome room to serve as detectives, and before long had all settled upon the same portion of the wall in one corner of the room. When this wall was opened, an old foul drain pipe was found which had been there for years and completely forgotten.

In the case of many animal forms of life, their predilection for special odors has been used with considerable success to attract to their destruction not only mammalian pests, but insects as well. In this way the geranium perfume (geraniol) has been used as a lure for the dreaded Japanese beetle, which it will attract from distances of a mile or more, and when these beetles reach the source of the odor they find awaiting them a very tasty meal of poisoned molasses. Similarly, an odorous constituent of the cotton plant, trimethylamine, has been used to attract the boll weevil, the object of such efforts of course being to induce the insects to collect in vast numbers where they can be killed *en masse*. A letter recently received from an investigator in the University of Western Ontario may be of interest to a fruit-growing state like Florida. It runs partly as follows:

> I am endeavoring to determine what constituents of the quince, peach and apple are attractants for the Oriental fruit moth, and we are basing our work on the assumption that insects detect odors which are perceptible to man. . . . I find that Power and Chesnut, of the Phytochemical Laboratory at Washington, have done considerable work on the apple and peach, but have been unable to find reference to work of a similar nature on the quince. This latter fruit is much more odorous than either of the others and certainly more attractive to the Oriental fruit moth.

Not long ago, I was visiting a farmer near South Bend, Indiana, who is, I am informed, the chief distiller of native essential oils in that part of our country. In addition to peppermint and seven or eight other oils, he often distils some catnip, because he said there was considerable demand for this last oil

from residents of the mountainous districts of the West and Southwest, who use it on the meat with which they bait their traps for mountain lions. Apparently, therefore, this odor has a special appeal not alone to the domestic cat, but to other members of the feline tribe as well.

Even the attitude of the hard-boiled business executive towards the use of perfumes in merchandising has changed strikingly during recent years, and has now given place to the slogan "Sell by Smell."

The *Daily News Record*, of New York, recently had the following to say on this subject:

The nose is a greater factor in business today than price, quality or quantity.

The advertising man writes a great deal about the glories of his merchandise, but the consumer gets going when he smells something he wants.

His nose knows!

The New York nostril has become tremendously sophisticated. The restaurants that say it with garlic are responsible to a great extent, it is claimed.

Men marry perfumes rather than women today. They take out a license when they encounter an extract they think they could endure at the breakfast table every morning for 40 years.

Shoes, leather and luggage, not to mention perfumes with a platinum price, sell largely because their aromatic qualities intoxicate.

A deal is closed and the goods practically delivered when the customer's nostrils begin to twitch like a setter's.

Olfactory orgies are not confined to women. The men sometimes keep it up until they have to be assisted to a taxi.

Some men even fiddle around drug departments in the hope that they will encounter an odor good for a misunderstood husband.

The girls no longer care who pays the rent if they can find a husband to keep them in imported perfumes.

People who object to paying about $60 a month to the landlord will pay that much for a bottle of perfume.

The diner-out turns to the right when he walks into a miasma that overcomes his powers of resistance.

The women manage to arrange a spree without a headache by going from one perfume counter to another, coaxing whiffs out of the various demonstrators largely responsible for the mixed odors of subway trains, department store elevators, etc.

Just as men formerly went from one cafe to another testing the hospitality of favorite Fausts, the women saunter from one store to another mixing their extracts.

The men are frequently slightly incoherent after applying their pet theories regarding the chemical properties of liquids and the women are usually a trifle irresponsible when they conclude their afternoon inhalations. A woman to-day must learn to be careful how she mixes her perfumes.

In the luggage departments the patron sniffs the grip of no regrets and if the odor is soothing there is a readiness to buy that would not otherwise be noticeable.

Russian leather, like Russian tea and vodka, acts immediately. The nasal organs whisper a message to the brain and the deal is closed while the customer is in a coma.

There are people who would rather stand around luggage departments than linger in an old-fashioned rose garden.

Parma violets are cabbage compared to the pungent qualities of a first-class luggage department.

The writer took note of several men buying new spring shoes a few days ago. Four out of five sniffed the leather before they even permitted a fitting. Mildly imbecile expressions scampered over their countenances when they encountered a favorite scent.

Experienced shoe men contend that you can lead a man to a leather but you cannot make him like the odor.

Shrewd business men are thus awakening to the powerful sales aid to be obtained from perfumes, and at last understand that an appeal to the nose is often far more potent than one to the eye. The actual value in cold cash of the despised sense of smell has been too often wholly overlooked or ignored by the high pressure salesman as well as by the head of his concern, neither of whom seems to have grasped the fact that scents may make dollars.

The sales appeal of perfumes may be utilized either to draw favorable attention to a normally odorless product, or to overcome a disagreeable smell. When a disagreeable odor can not be removed or destroyed, the only alternative is to

mask it by perfumes. Many markets are closed to malodorous products which would be opened immediately upon the removal of that objectionable feature. The total value of sales annually lost through failure to recognize these facts runs into many millions of dollars.

In the case of a product of established reputation and characteristic odor, it would probably be just as disastrous to change that odor as it would be to alter the form of the package or the trademarked name.

When a prospective customer picks up a cake of toilet soap or a package of cosmetic, her first impulse is to smell it. If the odor pleases, the other merits of the goods are likely to be inquired into, whereas if the goods are odorless or carry no special appeal, the examination usually goes no further. The first attempts to sell camels' hair shawls manufactured in Europe failed because these famous shawls as they were received from India exhaled a peculiar and characteristic odor which enabled even the inexpert to distinguish between the Indian and the European product, until it was discovered that this odor was due largely to oil of patchouli, and when this deficiency was made good in the case of the European product, its market expanded immediately.

The sale of a house may be decided by whether it smells old and musty or sweet and clean with the odors of new woods, fresh paints, fresh varnish and the like.

In the opinion of the manufacturers, the judicious use of appropriate and delicate perfumes and the air of luxury thus created have often determined the sale of their high-priced automobiles quite as much as the persuasive eloquence of the salesman.

In certain theaters, perfumes have been and still are at times disseminated throughout the entire auditoria by introducing them into the ducts of the ventilating systems; but the proposal to change these odors during the course of the performance in such fashion as to depict the changing moods presented upon the stage is practically impossible, because of the difficulty of completely replacing one atmosphere by another with sufficient speed. A musty upholstery in the theaters not infrequently has deterred patrons from returning. The use of incense in religious services is not only good ritual but excellent psychology as well.

Quite recently a very interesting upholstery material has been developed and already enjoys a considerable sale. It is manufactured by taking pig hair and subjecting it to the action of a mechanical "picker," which separates and fluffs up the hair so that when sprayed with rubber latex every individual hair will be coated completely. By simultaneously drying and curing, there results an exceedingly light, tough and springy felted mass of rubberized hair which has found an immediate market. Since both pig hair and rubber latex have unpleasant odors, it is doubtful if a pound of this new and useful product could have been sold if the manufacturers had not had the good sense to cancel this bad odor by the judicious use of perfume. The incorporation of less than one tenth of one per cent. of perfume achieved this at a negligible cost.

The clothy or faintly rancid smell of fabrics is generally to be ascribed to the oils and pastes essential to the weaving process or to give luster, smoothness or scroop to the finished goods (Turkey Red oil). This odor may be suggestive of castor oil and sulfur, and in the course of time tends to become more rancid. The use of suitable aromatics will readily and economically replace any initially unpleasant odor by a pleasant one and can also inhibit the development of rancidity. Perfumes especially designed for this purpose are now on the market. High-grade silk stockings are often faintly perfumed to increase their appeal to the prospective customer.

Scented cloth linings for bureau drawers, in place of sachets, are also available.

A field where there is still room for considerable improvement is that of the moth-proofing and insect-proofing of fabrics of all kinds, such as furs, carpets, etc. In the light of recent discoveries, it should be possible to accomplish this without leaving the goods permeated with objectionable smells. Of course, in the case of furs this has been avoided by simple storage at low temperature. Certain dyes have been discovered which are claimed to be effective insect-repellants. The fabrics dyed with such chemicals are neither malodorous nor ever in danger of insect attack.

It has proven a comparatively simple problem to incorporate in cleaning fluids chemicals which leave behind an agreeable aroma instead of the disagreeable odors hitherto so much in evidence when gloves, dresses and other clothing returned from the cleaners. Even perfumed laundry starch is now on the market.

The so-called Russia leather has always had a special appeal for me and possibly for others, not because the leather itself is any better than other brands, but because of the agreeable scent imparted to it by the birch oil used in its preparation. Several manufacturers of artificial leathers are scenting their products to make them smell like genuine leather at a cost of about $7.00 per 10,000 yards. Shoe dealers have had their goods either returned or have lost customers because of strong-smelling leather.

Linoleums, oilcloths and similar floor coverings are largely linseed oil products, and the odor of that oil is unpleasant to most people. The manufacturers at first went to considerable expense to lacquer the surface of the linoleum, so as to seal up the offending smell. Now they find that a better and a much cheaper way is to use such aromatics in the process as will either completely eliminate the bad smell or replace it with a faint and agreeable one.

The odor of printing inks is often fishy and rancid from the oils used in their manufacture, and this is especially objectionable when used on food packages, for many foodstuffs absorb odors with great avidity and the appeal of a product entirely satisfactory in all other respects may thus be completely destroyed and the sale of the product seriously injured. Such difficulties are easily overcome by the perfume expert. A Middle West meat packer has the Cellophane wrappers for his prize bacon packages printed with inks which themselves possess a bacon aroma. Makers of chewing gum and of confections are also printing their wrappers with inks perfumed in such fashion as to reinforce the olfactory appeal of the goods.

It has been suggested in connection with the matter of scented printing inks that a publisher might find it to his advantage to have his publications recognized not only by their general appearance but also by their characteristic odor, so that his books on scouting and woodcraft, for example, might be given a piney or woodsy fragrance, his detective stories the mysterious and piquant aromas associated with the high-class female criminals of such tales, and his love letters the heavy seductive narcotic perfumes of the languorous Orient.

Some books, the rotogravure sections of many newspapers and a number of handsomely illustrated magazines have rank cheesy odors, due in part to the casein used in the coating mixture, which bad odors should be eliminated as far as possible, and the remaining traces neutralized by perfume, just as traces of yellowness are corrected by suitable blueing.

The cost of imparting a pleasant odor to goods which are either odorless or

malodorous is usually very little and is more than repaid by the increased sales which result. According to the executive manager of one of our leading perfume houses, ten dollars' worth of perfume will scent 35,000 pounds of paper and enable a magazine publisher to get out an issue which any reader will be glad to hold close to his nose instead of having to sit by an open window with the breeze blowing away from him.

In some manufactures an odor specification for the raw materials would be immediately helpful. The kind of aroma to be imparted to a product should of course be appropriate, and need not always be of a floral character. Less than one cent's worth of perfume will completely mask the disagreeable smell of a gallon of glue, whereas in the case of a high-grade perfumed toilet soap it may cost several cents per cake.

In the matter of odor, manufacturers of household lacquers have markedly improved their products, and the producers of raincoats, wall finishes and other similar articles could profit greatly by their example.

A well-known company makes lamp shades by a process in which gelatin is used. In damp weather molds tended to grow on this gelatin and form black spots. The addition of a small amount of carbolic acid during the process prevented the growth of these molds, but on the other hand left an unpleasant odor. The company is therefore using a perfumed material as a sterilizer so that the lamp shades possess a pleasing faint aroma.

The determination of the particular perfume best suited to mask a given odor naturally requires skill and some experimentation. Certain fly sprays, composed of kerosene and pyrethrum powder, used to be scented with from 5 to 6 per cent. of oil of wintergreen. Such sprays can now be scented just as satisfactorily with two tenths of one per cent. of a different aromatic.

The rapid recent increase in the popularity of some brands of cigarettes is ascribed to the impregnation of the tobacco with small amounts of coumarin, whose odor may be likened to a combination of vanilla and new-mown hay; just as saccharin is added to other types of tobacco, notably the so-called plug cuts, to impart added sweetness of taste.

A certain Illinois department store, the majority of whose customers are women, encloses a perfumed "Thank you" with its receipted bills; and there is a subtle psychology about the practise of a Connecticut fire insurance company which solicits business by means of a folder exhaling the wet, burnt wood smell characteristic of a house which has been ravaged by flames.

Not long ago the Chicago Museum of Science and Industry wrote us that they had completed the installation of a model mine and wished to introduce into its ventilating system an odorous material which would impart to the mine air the damp, earthy smell characteristic of such shafts and tunnels. The problem was referred to a well-known perfume house, who have solved it, I understand, to the entire satisfaction of the museum authorities. Those of you, therefore, who have recently visited that museum in Chicago and have gone down this mine shaft, have breathed there this atmosphere without knowing that it was a synthetic one provided by the organic chemist.

The Huddersfield Line in England have perfumed their buses in some cases with pine and in others with rose or with violet, because they believed these three odors to be the most popular and because such treatment tended to eliminate the body odors which otherwise might be too much in evidence.

That their judgment as to relative popularity of odors was approximately correct is supported by the results of a most interesting questionnaire sent out some time ago to a large number of

people by the Cramer-Krasselt Company, an advertising corporation of Milwaukee, Wisconsin, asking their opinion on a list of 55 different smells. Through the courtesy of Mr. Aumueller, the manager of their direct service department, the results have been made available. The questionnaire was admirably simple and direct. All it asked in the case of each odor was that the voter should indicate whether he liked, disliked or was neutral (indifferent) to it. The odors preferred, in order of choice, taking only the first 10, were: (1) rose (85 per cent.), (2) pine (83), (3) lilac (83), (4) violet (77), (5) lily-of-the-valley (77), (6) coffee (76), (7) balsam (76), (8) cedar (73), (9) strawberry (68), (10) wintergreen and apple (67). Those disliked, arranged similarly, were: (1) perspiration (97 per cent.), (2) garlic (92), (3) rubber (81), (4) lard (79), (5) kerosene (77), (6) olive oil (70), (7) fish (70), (8) onion (66), (9) turpentine (63), (10) gasoline (59).

There will probably be quite general agreement as to the appropriateness of giving perspiration a high place in such a list, but there are many, especially in southern Europe, who certainly know their onions and who do not feel at all the same way about garlic, and the rubber manufacturers, handlers and dealers were inexpressibly shocked to learn that their product vied with perspiration and garlic in public dislike so far as its odor was concerned, for to them it had never seemed objectionable in the least. Not long thereafter, representatives of the rubber industry held a banquet in New York, at which boxes of red rubber bands of lilac fragrance were distributed, and rubber coasters with the odor of new-mown hay were used for the glasses, to show that the old familiar rubber smell could be very easily replaced by more agreeable ones. Less than one one-hundredth of a cent's worth of perfume will perfume an entire box of rubber bands.

The odors of towns and cities often constitute some of the most vivid recollections of a traveler. In my own case, for example, and I am equally certain concerning my wife, the most striking and lasting memory of Algiers is that of the smells of the Kasba or native part of the city.

Of the many problems still to be solved in this field, I might mention one of some importance to the state of Florida.

A correspondent writes as follows:

> An odor which I am particularly interested in overcoming is that contained in China wood or tung oil. This odor is reputed to be due to traces of valerianic acid. Methods have been patented for removing these odors by steam distillation, etc. However, the odor is not removed permanently as, due to oxidation over periods of time, the acids that supposedly cause this odor are split off from the glycerides and cause the evil odors. There then remains the addition of perfumes or pleasant-smelling substances to permanently mask these unpleasant odors. . . . The China wood oil is used on a household fabric and of course must contain no unpleasant odor.

Stinks, of course, have their practical uses as well as perfumes. In many instances, as employed, for example, by insects and various animals, they serve as weapons of defense; or emanations which seem mephitic to others may have powerful sex appeal to the particular organisms concerned.

In the closing days of the world war, we were using as a camouflage gas butyl mercaptan, which is the chief perfume component of the skunk's bouquet. Its purpose was to deceive the enemy and to cause him either to retire or at least to don his gas mask and thus reduce his fighting efficiency, because he never knew when this stink was being used to mask some deadly gas. Our own troops, on the other hand, knowing that the skunk gas itself was harmless, could ad-

vance through it with impunity and do their fighting without masks and with the assurance that before any killing gas was sent over with it they would be informed in ample time to protect themselves.

We have but to turn to nature to recognize the dominant rôle of odors. What would our northern forests be without the resinous fragrance of their conifers, or the ocean without its clean salty invigorating tang? Or, consider the unfortunate skunk, "one of the handsomest little animals you would want to see, but his good looks don't do him any good. He is an outcast from decent society; nobody wants him around; most people would go to any lengths to avoid him. And when you do get anywhere near a skunk, smell becomes the most important thing in life. It is a factor powerful enough to make you climb trees."

Why is it that the art of the perfumer is not taken so seriously as that of the musician, the painter or the sculptor? We teach our young people to distinguish musical sounds and color effects, harmony in music and in pictorial art, but the vast possibilities of artistic enjoyment provided in our wonderful olfactory endowment they are left to learn in the slow, unsatisfactory and casual school of practical experience, with the result that even our language lacks specific descriptive adjectives by which variations in odor can be accurately characterized in the same way that we can describe differences in color and in shade. There are masterpieces in perfumery, as in other arts, but those qualified to understand and appreciate them are few indeed. One of these old masterpieces of the perfumers' art is the famous Eau de Cologne.

While on this subject of the perfumer's art, I might call your attention to an amusing article, entitled "100,000,000 Guinea Pigs Can't Be Wrong," which appeared in the *Givaudanian* for October, 1933, part of which runs as follows:

Recently Consumers Research, Inc., issued a bulletin on perfumes and cosmetics in general, and when discussing many well-known brands on the market selling for 50 cents, 75 cents and a dollar per unit, tried to show that the true value of these products was 3 cents, 5 cents and 15 cents per unit. The interesting part is that the Consumers Research, Inc.'s analysis is correct—in its way.

One of these days we expect a pamphlet from Consumers Research, Inc., analyzing the value of the pictures hanging in the Metropolitan Museum of Art or in the Frick Galleries. There are many pictures there which were purchased for \$5,000, \$10,000, \$50,000 or even \$100,000 each. Consumers Research, Inc., will say:

Value of frames, for instance	\$15.72
Value of canvas	2.50
Paint used	7.20
Total value	\$25.42

Although the above calculations may be correct, I feel sure that the Metropolitan Museum would not at all feel that way about the prices it paid for its paintings.

As Dr. Arthur Selwyn Brown remarks:

The domain of olfaction is full of mysteries that are worthy of investigation. The manner in which moisture causes the odors of the essential oils in flowers and trees to escape into the air, and fascinate the insect world; the way in which a dog, a crow, a jackal or lion tracks its prey or finds a carcass; the manner in which bees, wasps and ants recognize members of their communities; the way a dog, purely by odor, determines whether a strange dog it meets is likely to be friend or enemy; the manner in which parasites find their hosts, or the reasons that butterflies and other insects have strong preferences for particular flowers and perfumes afford wide fields for study.

When this fascinating domain is more fully explored, we shall learn secrets of which we do not yet even dream.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE GREATEST STAR CATALOGUE

By Professor SAMUEL G. BARTON

DEPARTMENT OF ASTRONOMY, UNIVERSITY OF PENNSYLVANIA

A LOOK at the sky on a clear dark night gives the impression that the stars are so numerous that it would be a hopeless task to try to count them. This idea is expressed in Genesis 15:5, where we read, "I will multiply thy seed as the stars of the heavens and as the sand which is upon the seashore," and in Psalm 147:4, which says, "He telleth the number of the stars; he calleth them all by their names." Have the stars been counted? If the question refers to the stars visible to the naked eye the answer is yes, indeed. For a small sum a set of maps—star charts—can be purchased which will show the position of each star. The number of such stars, about 6,000 in the whole sky, is astonishingly small, and not more than 2,500 of these can be seen at any one time and place.

But if a telescope is used to reveal stars too faint to be seen with the naked eye the number of stars which can be seen is greatly increased with each increase in the power of the telescope. No one has determined the number of stars which have actually been seen with powerful telescopes. An elaborate program, however, is now being carried out in preparing a catalogue which will record the positions of an immense number of stars.

Soon after the great advantages of photography for mapping the sky were realized, an international conference of astronomers was called to meet in Paris in 1887 to discuss the possibility and advisability of charting the whole sky on a uniform scale by photography. Astronomers realized, as you soon will, that the project was far too large for any one observatory or country and that, if it was to be done at all, many must cooperate. Cooperation was necessary, too, because from no one observatory is the whole sky visible. This conference was the beginning of international cooperation in astronomy and led eventually to the formation of the International Astronomical Union, the present organization of the astronomers of the world.

This conference was attended by 56 astronomers, representing 19 different countries. After discussion they decided to prepare a catalogue giving the positions of all stars as bright as the 11th magnitude. An 11th magnitude star is only one hundredth as bright as the faintest star visible to the naked eye. They also decided to prepare a set of charts showing still fainter stars. They agreed that the photographs should be made with telescopes especially designed and made for this purpose with lenses 13 inches in diameter with a focal length of 11¼ feet. Such an instrument gives a good picture of a section of the sky two degrees square on an area of the plate 4¾ inches square. Since the moon is half a degree in diameter, the images of four full moons could be placed side by side on one plate. The charts are enlargements made twice the size of the original plates, that is, they are about 10 inches square. Officially, the whole project is known by the French title Carte du Ciel, but in English it is known as the Astrographic Catalogue and the Astrographic Charts. We are concerned chiefly with the catalogue.

After deciding upon this program 18

observatories scattered throughout the world volunteered each to take one of the 18 approximately equal sections into which the work had been divided. France took four sections, Great Britain three, Australia and Italy two each, and Argentina, Brazil, Chile, Germany, Mexico, Russia and Spain one each. The United States was represented at the conference by three astronomers, but did not volunteer and has not participated in the work. Some observatories have been unable to fulfil their promises and some changes have been made in the original assignments. Five languages are used in the catalogue, English, French, German, Italian and Spanish. As we now know, they were exceedingly optimistic in supposing that all the work would be completed in from five to ten years.

To get a photograph of a section of the sky the plate is placed at the focus of the lens of the telescope, and the telescope is then a camera. The lens must be one designed for photographic use. The larger the lens and the shorter the focus, the more quickly will any given star impress its image upon the plate. When the focal length is small, a large area of the sky will be shown on the plate and of course the scale will be small. In photographing the sky we have a choice—we can use telescopes which will record the whole sky on a few small-scale pictures showing large areas with little detail, or on many photographs showing smaller areas in greater detail, just as we can have a single map showing the whole of the United States or we can have maps of the same size showing single states or counties. The larger the scale of the plate the more accurately can the positions of the stars on it be determined. As the Paris conference decided to determine star-positions accurately it adopted a pretty large scale and designed the instruments accordingly.

Knowing the area of the sky shown on each plate and the total area of the sky, we can easily determine that at least 10,313 plates are necessary to cover the whole sky. But because of unavoidable and desirable overlapping of the areas covered by plates, 11,027 plates were actually used in photographing the sky once, involving a duplication of 6½ per cent. But as photographic plates frequently have defects, the conference had decided that another set of photographs should be made as a check, with their centers in different places, and consequently 22,054 plates were used in making the catalogue. An equal number is needed in making the charts. The enormous size of the undertaking is now apparent.

The total area of the plates used in photographing the sky once is equivalent to a single square plate 41½ feet on a side. If printed in the form of an atlas with pages the size of an ordinary typewriter sheet, 8½ × 11 inches, 2,660 pages would be required. The scale of the plates is equivalent to having the stars represented on a globe 23 feet in diameter.

The plates used are not ordinary photographic plates but are made of plate glass especially ground at the edges. The cost of the plates alone, for the catalogue only, has been estimated at from $8,000 to $10,000. They weigh nearly three tons. Three exposures of 6 minutes, 3 minutes and of 20 seconds, respectively, were made on each plate, the plate being shifted slightly between exposures. Counting 10 minutes for each plate the actual exposure time for the 22,054 plates amounts to 135 thirty-hour weeks or close to three years.

Obtaining the photographs, however, is but the beginning of the process. Each of these plates must be measured, that is, examined under a specially designed high-power microscope, and numbers must be assigned to each star to fix its relative position on the plate. The diameter of the star's image is also measured to determine the brightness of

the star. Professor Turner of Oxford tells us that the measurement of the plates of the section assigned to that observatory—1,180 plates, a little under 1,225, the average number for a section —required the services of four or five persons for about ten years, and that the printing of the catalogue for that section required another four years. This section of the catalogue consists of seven large volumes and gives 470,873 star-positions. Special efforts were made to get the work on that section done rapidly and economically; yet the catalogue for that section was not published until 1911. It was preceded by the Greenwich section only, in 1908, and that was 21 years after the Paris conference. In 1937 fifty years will have elapsed since the Paris conference. At present half of the sections of the catalogue are completed and published. The other sections are in various stages of progress, but some results have been published in each. Some are progressing rapidly, others have been virtually abandoned. It can scarcely be hoped that all will be completed by 1937, although pressure is being exerted. Financial difficulties are responsible for the delay, the world war of course being a great factor. Professor Turner in 1912 estimated the final cost of the catalogue at $2,500,000. Dr. Perrine, over the date September, 1932, wrote rather pessimistically: "After half a century of effort in which the resources of many of the principal observatories of the world have been lavishly expended, the work is far from completed. It is not possible to estimate with any degree of accuracy the cost of the work to date, but it cannot be less than ten million dollars gold." This includes both catalogue and charts. There is much doubt as to whether the charts will ever be published completely.

From the volumes of the catalogue actually published, embracing 11,000 plates from many scattered parts of the sky, I find that there are in the average 400 stars per plate, which indicates about 9,000,000 star images for all the plates. Considering that in making the plates the sky has been photographed twice and that there is a further duplication of 6½ per cent., but considering also that some stars have been recorded from one plate only, I estimate that the total number of stars represented will be about 4,500,000.

The whole astrographic catalogue will be equivalent to about 150 volumes similar in size to those of the Oxford section, or we might say to about 150 volumes of the size of those of the Encyclopedia Britannica, that is, to over six sets of the encyclopedia. This number of volumes would occupy over 13 feet of shelf space.

The catalogue gives us a record of the position of a great number of stars at a particular time. It can be used and is being used for statistical work on a variety of problems. I am especially interested in double stars, that is, stars very close together in the sky and presumably close together in space. Examination of the Astrographic Catalogue has enabled me to discover to date about 1,500 hitherto unknown double stars separated by 5″ or less. The catalogue will find its chief value, however, in the future. The solution of many important problems in astronomy depends upon a knowledge of the slow changes in the positions of the stars. One of our prized possessions is Bradley's catalogue, giving the positions of over 3,000 stars compiled from accurate observations made from 1750 to 1762. From these observations and those made on the same stars near the present time we are able to determine the slow motions of these stars accurately by reason of the long interval of time between the observations. At some time in the future, say 50 or 100 years from now, new photographs of the sky can be made and the motions of the stars in the present Astrographic Catalogue can be determined. We shall then know much more about the size and structure of the

universe. As present-day astronomers are greatly indebted to the astronomers of the past for their observations, we are under an obligation to the astronomers of the future, an obligation we hope to fulfil in the Astrographic Catalogue.

Although not designed primarily for that purpose the catalogue gives reliable information on the number and distribution of the stars. But the number of stars recorded is but a tiny fraction of the whole number. Even the plates for the Astrographic Charts made with longer exposures with these same instruments will show about 20 times as many stars. We can get a good idea of the number of stars by merely examining many small areas in properly selected parts of the sky as samples. Such selected areas have been examined with our most powerful instrument. The results show that an instrument as powerful as the 100-inch reflector at Mt. Wilson would reveal to the eye about 500,000,000 stars in the whole sky, and that photographs made with that instrument would show twice as many, that is, a billion, about 200 times as many as are contained in the Astrographic Catalogue, which has required over 50 years in preparation and which has cost millions of dollars. The astronomer's work is surely not near completion.

We feel certain that more powerful instruments will show more stars, although we do not know how many. Estimates can be made, however, based upon more or less secure foundation. A recent estimate assigns to our system of stars a mass equal to 170,000,000,000 times that of the sun, which is an average-sized star.

NUCLEUS AND COSMOS

By Dr. HENRY A. BARTON

DIRECTOR, AMERICAN INSTITUTE OF PHYSICS

Ladies and Gentlemen, if you are so kind as to listen to my talk, I can assume you are interested in what is the latest news in the science of physics—what are the things now coming to light, the discoveries which are important in forming the knowledge of mankind and which are likely to make the world different for you and for your children. Of course, no man is clever enough to predict just how fundamental discoveries will finally take practical effect. We only know from past experience that our deepest glimpses of nature usually lead to the most revolutionary advances. For example, it took a very penetrating mental eye to discern the atom in the depths of ordinary bulk matter, but the same light that disclosed the atom has since rapidly revealed all modern chemistry.

The improved vision of physics now goes deeper even than the atom and we have the right to draw many conclusions concerning the atom's inner construction and behavior. In particular, we have reason to believe that the atom has a heavy compact center or kernel which is surrounded by a kind of mush composed of electrons. It is something like a plum. It would, however, be no more reasonable to stop the story at this point than to stop the story of the plum with the kernel. We naturally ask what is inside the kernel and it is just what we know about the atomic kernel—or nucleus, as it is called—that I want to talk about, and a little about how it is found out. You will admit that this is looking pretty deep, and you can accept the assurance of every physicist that big things will come of these small ones.

The first man to become interested in the atomic nucleus was a Frenchman, Becquerel, in 1896; but it remained for

Ernest Rutherford—now Lord Rutherford—first to grasp the concept of the nuclear atom, the atom like a plum. His idea was not in any sense a guess but rather an interpretation of his own careful experiments. Becquerel discovered the rays of radioactivity, and his work was quickly extended by Madame Curie and her husband. Rutherford and others showed in 1911 and the next few years that the rays came from the nucleus, not from the outer "pulp" of the atom. All the properties of these rays—their nature, their intensity, speed, etc.—immediately became the bearers of information about the object—the nucleus—that sent them out.

It has been shown that there are three kinds of radioactive rays: the electrically positive, the electrically negative, and a kind that is neither. The positive rays are called alpha-particles and they go very fast, the negative rays are electrons which go even faster and the others are like very penetrative x-rays, which, being a kind of light, go as fast as light—which is as fast as possible. Alpha-particles are going 12,000 mi./sec., beta-particles almost (but not quite) as fast as the x-rays, and the latter 186,000 mi./sec. Alpha-particles have been identified as the kernels of helium atoms. The beta-particles turned out to be electrons—in no way different from the electrons dancing to your bidding in the tubes of your radio set—except that they are going very fast.

The upshot is that the nuclei have volunteered the information that they are in part made of electrons and alpha-particles. But that is not the last of it. About the same time, Sir J. J. Thomson and later Dr. F. W. Aston began weighing atoms by a very ingenious method. They were actually weighing the atomic nuclei—because it turned out from Rutherford's experiments that the pulp weighs practically nothing and the nucleus contains practically all the weight of the atom. Once the nuclear weights were known, it became possible to test whether nuclei were made up only of alpha-particles and electrons. Well, the idea could not be held for a moment, because on the chemical scale an alpha-particle weighs four units and there exist in nature atomic nuclei weighing 1 unit, 6 units, 7 units, 9 units, etc., which could not be made of unbroken 4-unit alpha-particles any more than 35 cents or a dollar and a half can be made out of unbroken bills. Some kind of a quarter was needed. I ought to have said that the electrons in the nucleus do not count because they are so light we can forget about their contribution to the total weight. On our analogy they would be much less than pennies, and even America's first great physicist, Benjamin Franklin, would not mind our ignoring them.

The one-unit nuclei I mentioned are hydrogen nuclei, usually called protons. They are the kernels of hydrogen atoms. This, by the way, will not be new information to those who have read in the papers about the discovery of a still heavier hydrogen weighing two units instead of one. Since the alpha-particles weigh just 4 times the ordinary hydrogen nucleus and the other atomic nuclei likewise all weigh simple multiples, it was natural that physicists came to think that all nuclei are built up really of protons and electrons—nothing else. But since alpha-particles seemed to be parts of nuclei it was supposed that the protons frequently got packed into alpha-particles and the nuclei were then made up of these packages plus one or more loose protons.

Unfortunately, only the nuclear weights suggested that protons were the bricks of the nuclear structures. There was no positive proof of it. The radioactive atoms never gave any hints by sending out single protons. Furthermore, the information gathering was limited by the fact that no attempt to attack or study the nucleus by artificial means

was successful. The nuclei volunteered information in the shape of the radioactive rays, but none of the accepted third-degree methods of the laboratory succeeded in forcing the disclosure of further information—not, that is, until 1919—23 years after Becquerel made the first discovery of a nuclear phenomenon.

In 1919, Rutherford—the same Rutherford—at last found out how the human race could do something to the smallest things in the world. He showed that when he let the alpha-rays from radium fall as bullets on nitrogen atoms, some of the bullets would hit the nitrogen nuclei and knock out the very proton bricks that physicists had suspected nuclei were made of. Rutherford applied all his intelligence and skill to the methods of a child—breaking up things to see what they are made of—and thereby made himself the world's first successful alchemist. Because in knocking out a proton from the nitrogen nucleus he changed that nucleus into a different kind—a different chemical kind of atom. It is interesting to realize that we are living in the age in which the goal of the alchemists, sought for many centuries, was finally attained.

What makes such experiments as Rutherford's so difficult is that only a very small fraction of the shots fired at atoms succeed in smashing their nuclei. Another thing is that radium is very rare, so one's supply of alpha bullets is extremely limited. This is why no very startling further progress was made for some years.

Then, three years ago, nothing less than a new fundamental constituent of matter was isolated—a thing now called the neutron. It seems that the story about the nucleus was incomplete. Chadwick, of Rutherford's laboratory, identified still another kind of ray coming out of nuclei. He found these new rays were emitted from the nuclei of certain light elements like beryllium, when they are bombarded by alpha-particles. The rays are particles—not anything like x-rays—but yet not charged particles like alpha-particles and electrons. They were neutral and so were called neutrons.

In 1932 yet another ray was discovered, this time by Carl D. Anderson, working with Millikan in this country. These rays were knocked out of atomic nuclei when the latter were struck by cosmic rays. More recently, it has been found that certain radioactive rays can eject them, too. They are just like electrons but with one essential difference—they carry a positive charge of electricity instead of a negative charge. If one were put in a radio tube it would back up or go in the opposite direction to the ordinary electron. They are called positive electrons or positrons for short.

So our list of nuclear building blocks has been revised. We now have protons, familiar negative electrons, newly discovered positive electrons and neutrons. The augmented list is a victory of physical discovery, but it is a defeat for the physicist in his aim to picture nature in terms of as few elements as possible. He has not rested under the sting of this defeat and now has reason to believe that the old proton was not an element after all but rather a combined neutron and positron. This reduces the elemental stuff of the nuclei to three kinds instead of four. Thus do physicists answer our original question: What is inside of the nucleus? Electrons, positrons and neutrons.

They are going on now to find out how these elements are arranged, how put together, to make nuclei. Again the wise-childish technique of breaking things up has come into use. Now, however, it is no longer necessary to use the scarce and expensive alpha-rays for bullets. Apparatus has been developed to generate high voltages, and these can be applied to huge vacuum tubes in such a way as to accelerate hydrogen and helium nuclei which have been stripped of their electronic pulp by laboratory

means. The result is fast particles as effective as those found in nature and much more abundant.

For example, Cockcroft and Walton—of Rutherford's laboratory again—built up an elaborate apparatus capable of accelerating particles with 600,000 or so volts. They used protons (that is, hydrogen nuclei) for bullets and shot them against a piece of lithium. Lithium is a mixture of atoms weighing 6 units and atoms weighing 7 units in the chemist's scale of atomic weights. During the bombardment they found that the lithium target was emitting rays of something more powerful than the fast protons which induced the effect. But these "new" rays turned out not to be new in nature. They soon were proved to be the same old familiar alpha-particles. But the result was tremendously new. The experiments went on. It was found that the alpha-particles came out in pairs, that each pair had energy of motion equal to 15 million volts—surprising facts, but ones that carry a suggestion of the most fundamental significance for the world.

What we apparently must think about the Cockcroft and Walton experiment is that frequently a proton struck and entered a Li 7 atomic nucleus. Then a kind of alchemical reaction took place and there were produced two alpha-particles out of the original striking proton and the struck nucleus. Furthermore, these alpha-particles actually shot out (or flew apart) with greater energy than was put in. Atomic energy was released. That energy locked up in the mass of the nucleus—of which you have heard it said that a spoonful of water contains enough to drive the *Leviathan* across the Atlantic—escaped.

I want to make this idea as clear as I can. Go back to more familiar things. Start with coal—ordinary coal being burned in a power house. The combustion converts chemical energy into heat. The boiler and the turbine convert this heat into the mechanical energy of a turning steel shaft. This drives a generator in which the mechanical energy is converted into electrical energy. Thus it is a very familiar idea that energy can exist in different forms and can pass from one form to another.

Einstein, in his theory of relativity, states that matter itself is a form of energy and suggests that the matter in a particle like a nucleus may be consumable, or convertible into another kind of energy. It is this energy of mass which is generally known as atomic energy, and it is very concentrated. The idea has been a plaything for imaginative people, but the experiment of Cockcroft and Walton brings it down to the solid ground of actual human experience. For the amount of energy of motion in the two flying alpha-particles was exactly the amount it should be. That is, the proton and the lithium nucleus weighed just a little more than the two alpha-particles. Taking the difference in mass between the reacting materials and the products of the reaction, Cockcroft and Walton found that the energy of mass set free is just enough to produce the energy of motion observed. It is reasonable to suppose that just as the ancients developed the production of heat from chemical reactions, just as James Watt developed the steam engine, and just as Faraday, Henry and others developed the dynamo, so Cockcroft and Walton have begun the development of a process equally significant to the human race.

The title of my talk was "Nucleus and Cosmos," and you will observe that I have left but a minute for the latter. A minute to talk about the universe! But you see from what I have said that the nucleus is of cosmic importance. In fact, the cosmos is mostly made of nuclei, almost all the energy in the universe is in the nuclei, and even the

famous cosmic rays are almost certainly some kind of nuclear phenomenon. Probably in the hot cores of the stars, there does not exist any matter as we know it, no plum-like atoms. The pulp is burned away and nothing is left but bare kernels, neutrons and free electrons, striking up against one another in inconceivably violent agitation. There is no ordinary chemistry—only the kind of chemistry that Cockcroft and Walton found, nuclear chemistry or alchemy. The experiments of the last few years have assured us that man will be able to investigate—by his own efforts—the nuclei of the atoms. It is perhaps not too much to say that the field just opening and now definitely in view is larger than the field of all physics from the beginning of history to now.

NEW CROPS FOR THE AMERICAN SAHARA

By Dr. WALTER T. SWINGLE

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To most people the word Sahara brings to mind a sandy desert waste, difficult if not dangerous to traverse because of the scarcity of water, and rendered doubly dangerous by blinding sand storms caused by hot, dry winds. However, all travelers agree that, wherever water is available in Saharan regions, there are found oases that show luxuriant vegetation, abundant production and picturesque beauty. More and more is being heard about these attractive features of desert life.

Few persons, however, realize that in the United States we have large areas which have climates that are extremely similar to those found in some of the best known parts of the Sahara desert and that in these sections of our country are to be found, as well, some of the most productive areas of the United States, regions which, thanks to irrigation, rival if they do not excel the finest oases of the Sahara itself in beauty, charm and in the bountiful production of human food.

Few people realize that no other populous, highly organized, temperate-zone country includes within its borders such large areas with typical Saharan climates through which are scattered, wherever water is available, magnificent productive oases. The Old World countries, France, England, Spain and Italy, possess, it is true, colonies which have Saharan climates, but none of them have within their own borders Saharan climates such as are found in the United States.

The North European settlers who live in these distant Saharan colonies, all but a few of them, move out en masse to cooler regions as the torrid heat of summer comes on, and the few who remain behind, in lonely isolation, to hold vital posts, do not have the proper attitude of mind to conduct scientific work or even to study critically and improve cultural practises. The natives of such Saharan oases who do live there the year 'round, are not qualified by disposition, nor by training, to question the time-honored practises of their forefathers, much less to make any scientific observations.

In no part of the world other than the United States do North Europeans reside the year 'round in large numbers in these Saharan climates. There are doubtless many more residents of North European ancestry in the hot valleys of Arizona and California than in all the rest of the Saharan climatic regions of the world put together. Many of these

residents of the oases of our Southwestern States are expert plantsmen, skilled engineers and some of them are high-school, college or university graduates. Thanks to this unusual situation, the study of desert crops and their culture in this country has made remarkable progress in recent years.

The culture of the date palm, one of the most characteristic and most beautiful of the crop-plants of the Old World oases, was undertaken early in this century as a definitely planned study to determine the possibility of introducing into the United States the crops of the Old World Saharan oases. This program was initiated by importing a large collection of the best date varieties of the Old World and planting them in several testing gardens in Arizona and California in cooperation with the state agricultural experiment stations of those states. Since then the date palm has been studied in the United States as nowhere else in the world.

Repeated trips to the date regions of the Old World, made by date experts under the auspices of the Division of Plant Exploration and Introduction of the U. S. Department of Agriculture and by private nurserymen, resulted in bringing into this country the best date varieties of all the leading date-growing regions of the Old World. Each date-growing country of the Old World has, to be sure, its own varieties of dates, but no country, other than the United States, has such a complete collection of the choice varieties of all countries, including well over one hundred date varieties from various parts of the Old World. These have been secured from the oases of Northern Africa, Egypt, Arabia, Mesopotamia, Persia and Baluchistan, and are now being tested in the experimental date gardens of California, Arizona and Texas.

Date culture has already become a promising new industry in California and Arizona, and some of the date gardens in these states are probably the best managed and give the highest yields of any in the entire world. The American public is coming to appreciate the delicious home-grown dates that are packed for the consumer, in an extremely clean and attractive way, practically fresh as picked directly from the trees.

The date palm can not be grown successfully except in a Saharan climate. There is an Arab proverb, which states that the date palm must have its head in the burning fires of the sky and its feet in running water. In the rich soils of southeastern California and southern Arizona, the date palm grows with extreme rapidity and comes promptly into bearing. No other commonly grown crop yields any such quantity of human food as the date palm, and the fruits are of such choice flavor and of such attractive appearance that they are almost to be classed as confectionery rather than as ordinary food. Besides, the exceptionally high and well-balanced mineral content of dates seems to render them an exceedingly healthful food—even for children and invalids. At the present time about four or five million pounds of dates are produced each year in the southwestern states, while about forty to fifty million pounds are imported into this country from the date-growing lands of the Old World.

As would be expected, American date growers and their technical advisers have made one discovery after another concerning date cultivation and production until it is no exaggeration to say that more progress has been made in improving date culture in the United States during the past twenty years than has been made by Old World date growers in the past twenty centuries. New methods of planting and of transplanting date palms; new methods of pruning them and of thinning the crop; new methods of picking, curing, sterilizing,

packing and storing the fruit, have not only been discovered but have been put into practise by intelligent American date growers. In the field of pollination of the flowers in particular, new and spectacular discoveries have been made.

People not familiar with the date palm may not realize that the pollen is produced on male palms which yield no fruit. In remote antiquity, some five or six thousand years ago, the Sumerians in Mesopotamia discovered how to pollinate the female date palm by tying a short spray of male flowers in each flower cluster of the fruiting palms. Only two or three male palms are needed for a hundred fruiting palms, and to-day all the Arab date growers of the Old World, as well as all the American date growers, practise this system of artificial pollination. This is a great advantage over the haphazard pollination of date palms growing in a wild state, where the wind blows the pollen about from the male palms to the fruit-bearing ones, which exist in about equal numbers when grown from seeds as date palms originally were grown.

The discovery about pollination which has come as a surprise to fruit growers and to scientific botanists the world over is that the pollen from different male palms has been found to exert a very definite influence upon the time of ripening of the fruit.

In some parts of the Southwest the summers are so hot that most date varieties ripen too early and tend to shrivel in the burning heat of later summer. In other regions the summer heat is not adequate to ripen all the crop before rainy cool weather begins in autumn, with the result that often a large fraction of the crop may hang on the palms in an immature condition far into the winter, with heavy losses from rain, which is very detrimental to the ripening of the fruit. By using the pollen from selected male palms it has been found possible to control ripening in an exceedingly satisfactory way, and this control is now being used on a commercial scale in some of the large date plantings in the Coachella Valley in Southern California.

There are thousands of beautiful date palms growing in the vicinity of Palm Springs, Calif., and Phoenix, Ariz., two of the most famous and most beautiful desert resorts in America, and these have attracted the enthusiastic admiration of great numbers of winter visitors. It is nó exaggeration to say that the date palm has contributed more than any other cultivated crop to the beautification of the landscape; and furthermore, date gardens lend a characteristic desert atmosphere that nothing else could give.

The skilled Arab cultivators of the Old World plant, under the half-shade cast by the feathery foliage of the date palm, choice fruit trees of all kinds—oranges, figs, apricots, etc.—which thrive to perfection; and underneath the deeper shade of these fruit trees, sheltered from the burning sun, grow flowers and vegetable crops, thus making the land support willingly three tiers of crops—first, the leafy palms high in the air, then the friendly fruit trees, having their laden branches within easy reach, and finally, below them, vegetables, berries or lovely flowers. Our own date growers have already discovered that oranges, grapefruit and other citrus fruits thrive unusually well under the shifting half-shade of the date palm. Soon we too may expect to see luxurious gardens under our own lofty date palms, rivaling or excelling in charm those of the famous oases of the Old World.

PROTIUM—DEUTERIUM—TRITIUM THE HYDROGEN TRIO

By Dr. HUGH S. TAYLOR

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THREE months before the outbreak of war in 1914 an international scientific race had just been concluded. Soddy of Aberdeen had found that radio-lead from thorium sources had an atomic weight of about 206. Richards and Lembert in Harvard and Hönigschmidt in Vienna had shown independently that radio-lead from uranium sources had an atomic weight of about 208. Ordinary lead was known to be about 207. Soddy's concept that substances could exist with identical, or practically identical, chemical and spectroscopic properties but different atomic weights was established. Soddy suggested a name for such substances, isotopes, because, though different in mass, they occupied the same place in the chemist's periodic table of the elements. We now know that isotopes of the same element have the same net positive charge on the nucleus and the same system of external electrons. It is the net nuclear charge, not the mass of the nucleus, which determines the position in the periodic table.

Aston, who after the war returned to the Cavendish Laboratory in Cambridge, England, developed a mass spectrograph to determine masses of individual charged particles and in November of the year 1919 supplied definite proof that the rare gas, neon, existed in at least two isotopic forms of masses 20 and 22. He thus extended the concept of isotopes to elements which were not radioactive in their origins. There followed a decade of activity in which, with the mass spectrograph progressively refined, an increasingly large number of elements were shown to be isotopically complex. There are, for example, eleven isotopes of tin. Some elements persistently proved to be simple. Carbon, oxygen and hydrogen were among those so regarded at the end of the ten-year period.

Early in 1929 the complexity of oxygen was established by Giauque and Johnston of California, using a novel method of attack, by examining the absorption of light by air. They found absorption bands which were interpreted as belonging to compounds containing two new oxygen isotopes, one of mass 18 and a much rarer one of mass 17. Oxygen, of mass 16, had been used as the standard of mass reference for all the other elements both for historical reasons and because of its assumed simplicity. Its established complexity at once raised doubts as to the simplicity of carbon and hydrogen. In the case of the former, the doubts were resolved by the discovery, in 1929, of a rare isotope of mass 13 by Birge and King, again from a study of the band spectra of gaseous carbon compounds, among others that of carbon monoxide. Birge and Menzel calculated that discrepancies between the chemical atomic weight and the mass spectrograph value for hydrogen would be resolved if hydrogen contained about 1 part in 4,500 of an isotope of mass 2. It was this theoretical calculation which provided the spur for an experimental search for such an isotope by Urey, Brickwedde and Murphy, jointly, at Columbia University and the U. S. Bureau of Standards. They announced early in 1932 that, by frac-

tional distillation of liquid hydrogen, the heavier isotope concentrated in the residue and that its presence could be demonstrated by the appearance of a faint spectral line in the hydrogen discharge near the ordinary line of atomic hydrogen and spaced from it at such a distance as would be demanded theoretically for an atom with a charge of unity (that is to say a hydrogen isotope) but having a mass of two.

Atomic weight determinations, mass spectrographic and light absorption measurements only demonstrate the existence, the relative abundance and the masses of isotopes. The practical identity of their chemical properties, emphasized at the outset by Soddy, had been utilized in the case of radioactive isotopes for chemical indicator purposes; the desirable goal of the scientist, the separation of the isotopes of an element and the separate examination and comparison of their properties, remained until a year ago unattained. An enormous amount of effort has been expended in the attempts at separation. These must be based on differences in properties which depend essentially on mass or on chemical reactivity. For a decade and a half prior to 1933 a variety of trials were made. Separation was attempted by fractional diffusion, by thermal diffusion, by centrifugal separation, by fractional distillation and evaporation at low pressure, by migration of isotopic ions under the influence of an electric current, by preferential excitation to photochemical reaction of one or other isotope using light absorbed by one and not the other. The net success was vanishingly small. One or other method gave separations of one or two parts per thousand at such a prodigious expenditure of effort that the recovery of the pure components of an isotopic mixture seemed to be an unattainable objective. The hydrogen isotopes, of masses 1 and 2, represent the most favorable case, since the mass difference is 100 per cent. Even in this case the problem seemed to be discouragingly difficult when it was shown that the fractional evaporation of 40 liters of *liquid* hydrogen until only two liters of *gas* remained raised the concentration of the heavier gas only to 1.5 per cent. Hertz in Germany has separated the two isotopes by fractional diffusion through special porous material to yield the separate constituents spectroscopically pure. His method, however, only yields a few cubic millimeters of gaseous product.

The development which revolutionized the whole subject of isotope chemistry is due to the late Dr. E. W. Washburn of the U. S. Bureau of Standards. Washburn determined, late in 1931, to test the efficiency of electrolysis of water solutions as a method of concentrating the hydrogen isotopes. While his own experiments were in progress, he secured samples of water from commercial cells which had been used for several years in the electrolytic production of hydrogen and oxygen. Urey analyzed this water for him by the spectroscopic method and found an enrichment of the mass 2 isotope. Washburn himself found that the density of the water was greater than that of ordinary water by 50 parts per million, a further evidence of enrichment. As Washburn and Urey wrote in their joint communication "the above results are of great importance, for we now know that there are large quantities of water in these electrolytic cells containing heavy hydrogen in relatively high concentrations and, also, there is available now a method for concentrating this isotope in large quantities." Washburn's determination of the abnormal density of water from electrolytic cells will take rank with those classical determinations by Lord Rayleigh of the densities of chemical and atmospheric nitrogen, from which,

with the work of Sir William Ramsay, there resulted the discovery of the rare gases of the atmosphere, helium, neon, argon, krypton and xenon.

The isolation of the mass 2 isotope in approximate purity was not achieved by Washburn. The race was to the swift and to those richer in available resources of apparatus and men. In rapid succession, from the University of California, Princeton, Cambridge, England, Columbia University, Frankfurt and Vienna came records of the success of Washburn's method in producing water in which with continued electrolysis 30, 60, 92, 99.9 per cent. of all the hydrogen atoms had a mass of two instead of one. Since the mass of the molecule H^2_2O would be $2 \times 2 + 16 = 20$, whereas ordinary water would be $2 \times 1 + 16 = 18$, it is evident that, granting equal volumes of the two molecules, the new water might have a density of $20/18 = 1.11$. The experiments were followed by the changing density of the product, and it is now known that heavy water with hydrogen of mass 2 has a density of 1.1079 at 25° C. referred to ordinary water at the same temperature.

Shortly after the isolation was accomplished, Urey, Brickwedde and Murphy christened the isotopes; hitherto this had not been necessary with isotopes since there had been no chemistry of separate isotopes to be considered. The discoverers of heavy hydrogen suggested, for hydrogen of mass 1, the name protium, since this would conform with current usage of the name proton for the nucleus of the hydrogen atom. For the isotope of mass two they proposed the name deuterium, which, for the nucleus of this atom, suggests deuteron or, more briefly, deuton, the nucleus of mass 2 and unit positive charge. They also suggested that, if the isotope of mass 3 were discovered, the name tritium might be considered. These names have found general acceptance, except in England, where, following a suggestion from Lord Rutherford's laboratory, the name "diplogen" has been employed. The best excuse for this latter is that it gives "diplon" instead of deuton, which latter does not find favor with the English scientists who, with colds in their heads in winter time, may confuse deuton with the "neutron" the particle of mass 1 and zero charge. Considerable discussion has arisen as to the symbols to be employed. Previous custom has sanctioned H^1, H^2 and H^3 for the symbolic representation. There is, however, an increasing use of H for H^1, of D for H^2 and of T for H^3. Fortunately, D and T have not hitherto been used as symbols for any elements; also, D stands, equally well in England and elsewhere, for both deuterium and diplogen.

For the technique of preparation of pure heavy water or deuterium oxide, the Princeton procedure may be cited, since, in this manner, about 13 tons of commercial electrolyte corresponding to upwards of 50 tons of ordinary water have already been treated to yield approximately one pound of the purest heavy water. About 15 gallons of commercial liquor are electrolyzed daily to one fifth volume in a battery of 960 cells using nickel anodes and iron cathodes. The residue is distilled to remove excess electrolyte, and the distillate after addition of alkali is passed to the second stage, a unit of 160 cells shown in the diagram, Fig. 2, on page 369, where it is again electrolyzed to one fifth volume. These two stages concentrate the deuterium from 1 part in 1,600 to 0.25 per cent., and 1 per cent., respectively. From the third stage onwards a modified form of electrolysis is employed in which the evolved hydrogen (containing deuterium) and oxygen gases are recovered as water and passed back to the preceding stage of electrolysis. The experimental arrangement is shown in Fig. 3. The

successive stages handle successively smaller volumes of water the concentration of deuterium in which rises by steps from 1 per cent. to 4, 13, 35, 95 and 100 per cent. D_2O. The electrolytic fractionation factor is about 5, that is to say, the gas evolved is about one fifth as concentrated in deuterium as the water from which it is evolved. Hence the separation that is achieved.

The product has unique and characteristic properties. Its density relative to ordinary water at 25° C. is 1,1079. It melts at 3.82° C. and boils at 101.42° C. It has a maximum density, not at 4° C. as with ordinary water, but at 11.6° C. It is 25 per cent. more viscous than ordinary water at 20° C. but has a smaller surface tension. Salts are less soluble in it by about 10 per cent., and the electrical conductance of salt solutions is less than in light water.

There are three kinds of hydrogen molecules that can arise from light and heavy hydrogen atoms, namely, H_2 molecules, D_2 molecules and the mixed molecule HD. To analyze mixtures of such gases a special mass spectrograph has been developed by Dr. Bleakney, of the Princeton Physics Department. It is evident that the molecules just discussed will give rise to ions of masses $2(H_2^+)$, $3(HD^+)$, and $4(D_2^+)$. In addition to these, atomic ions of masses 1 and 2 (H^+ and D^+) can also arise and, from these, triatomic ions (HHH^+) of mass 3, (HHD^+) of mass 4, (HDD^+) of mass 5 and (DDD^+) of mass 6. Bleakney's method permits him to sort out these various possibilities so that he can estimate how much protium (H) and how much deuterium (D) is present in a given sample. Fig. 1 shows the results of one such analysis of a deuterium rich sample.

Using such a method of analysis it has been found that the deuterium content of normal rain water is 1 part in 5,000 of the total hydrogen present. This is a much greater abundance of deuterium than is present in the chromosphere of the sun as spectra at the last eclipse definitely showed; it points to a tremendous preferential loss of light hydrogen during the earth's formation. The announcement by Lord Rutherford of the synthetic production of hydrogen of mass 3, tritium (T) by bombardment experiments of deuterium with high-speed deutons lent considerable interest to a determination by the Princeton Physics Department of the tritium content of the purest deuterium oxide water prepared in the Frick Chemical Laboratory. With a new and specially refined mass spectrograph it has now been shown that our purest heavy water contains approximately 1 part in 200,000 of the tritium atoms. This means that, in ordinary water, the tritium content is not more than 1 part in a billion. Tritium, therefore, becomes the youngest and rarest of all the isotopes yet discovered in natural occurring substances. Since heavy deuterium water costs, at a conservative estimate, \$5 per gram, it is evident that, with a 100 per cent. efficiency of recovery of its tritium content, pure tritium water, T_2O, would cost at least \$1,000,000 a gram or water roughly twenty times the cost of radium. Such are the paradoxes of modern isotope chemistry.

Using the same method of analysis it is possible to follow the rate of reaction of one isotope of a given element with its own isotope. It has been shown, for example, that H_2 molecules will react with D_2 molecules to form HD molecules at temperatures as low as that of liquid air, with catalysts such as chromium oxide and nickel which are active in catalytic hydrogenation processes. These results indicate that the high temperatures necessary in industrial syntheses such as those of ammonia or wood alcohol are required not for the activation of the hydrogen but for the activa-

tion of the molecules with which the hydrogen has to react. If surfaces can be found as active towards these molecules as present available surfaces are with respect to hydrogen, tremendous improvements would be possible in such industrial operations, under much simpler working conditions. Deuterium points the direction which research in technical catalysis must take.

Biologically, heavy water has proved to be of the utmost interest. Seeds of the tobacco plant do not germinate in heavy water. Fresh-water organisms such as tadpoles and guppies die quickly when placed in heavy water. Unicellular organisms, such as paramoecium or euglena, are more resistant, but are eventually killed. The luminescence of bacteria is modified in heavy water media, and the rate of respiration markedly reduced. Yeast ferments sugar in heavy water at only one ninth the rate in ordinary water. The enzyme catalase present in the blood stream and whose function it is to destroy hydrogen peroxide does so at only one half the normal rate in 85 per cent. heavy water. The action of the heavy water may be likened to that of a generally unfavorable environment leading to progressive changes in the cell. It would seem that the changes observed are the result of differential effects on the rate of biochemical reactions, examples of which have just been given in respect to enzyme reactions. The use of heavy water as an indicator of reaction mechanism in biological systems is evident from reports of recent English work in which it has been shown, by experiments conducted in heavy water, with organisms such as *B. coli* and *B. aceti*, that the present accepted mechanisms for their activity need to be modified in the light of results obtained with media containing deuterium instead of hydrogen.

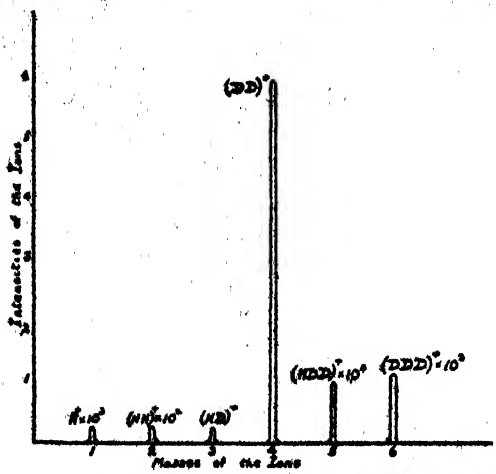


FIG. 1. DIAGRAMMATIC REPRESENTATION OF AN ANALYSIS BY THE MASS SPECTROGRAPH OF A GAS SAMPLE RICH IN DEUTERIUM. EACH PEAK REPRESENTS THE ABUNDANCE OF THE ION OF MASS GIVEN ALONG THE HORIZONTAL AXIS OF THE GRAPH. THE SCALE FOR THE IONS H^+, $(HH)^+$, $(HDD)^+$ AND $(DDD)^+$ IS MULTIPLIED BY THE AMOUNTS SHOWN AGAINST EACH PEAK TO PERMIT THEIR REPRESENTATION ON THE SAME DIAGRAM IN SPITE OF THEIR GREAT RARITY. THE ANALYSIS YIELDS 98 ATOM PER CENT. D AND 2 ATOM PER CENT. H.

The known compounds containing hydrogen are numbered in the hundreds of thousands. It is evident that an overwhelming program of research replacing hydrogen by deuterium is possible. Judiciously conducted, such a program will aim at the preparation of materials with which problems in physico-chemical science may be tested. There are already the beginnings of such a program to be recorded. A number of exchange reactions between heavy water and different substances have thrown light on the problems of mechanism involved. Thus, ammonia gas, NH_3, exchanges very rapidly with heavy water, D_2O, to give ammonia in which the hydrogen atoms are replaced by deuterium atoms to an extent depending on relative concentrations. In cane sugar, however, only about half the hydrogen atoms are readily replaced and these atoms are those present in the molecules as hydroxyl (OH) groups. Acetylene,

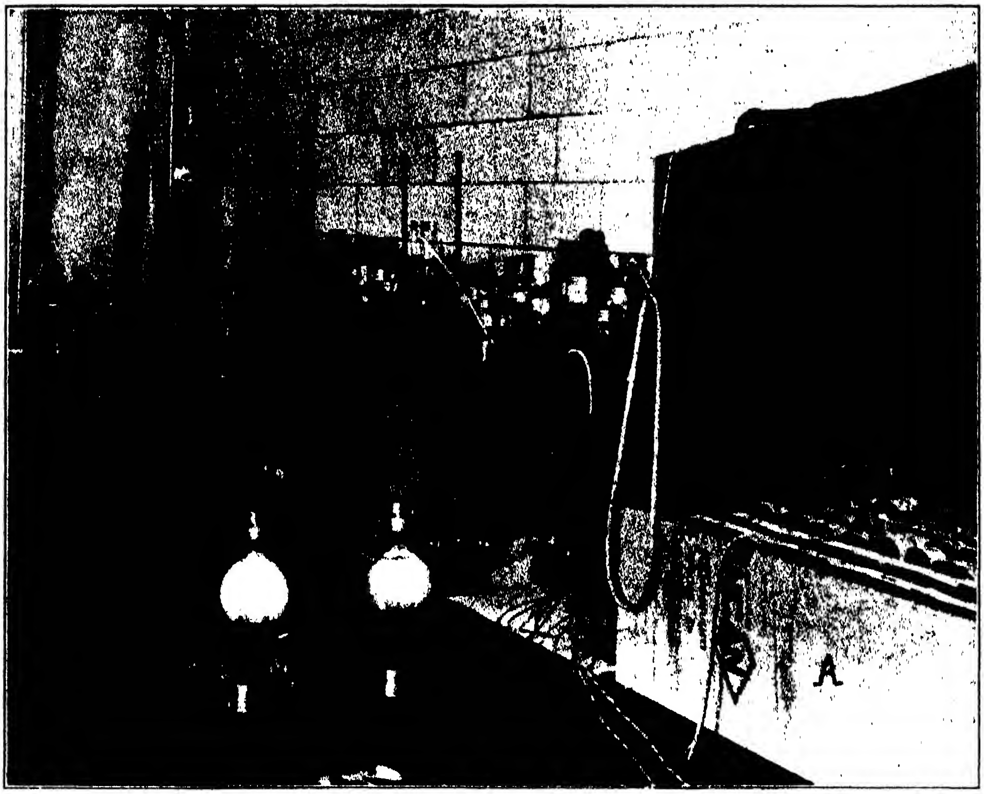


FIG. 2. GENERAL VIEW OF ELECTROLYTIC CONCENTRATION OF HEAVY WATER
TANK A TO RIGHT CONTAINS 160 UNITS FOR THE SECOND STAGE OF THE ELECTROLYSIS. TANK B, SHOWN IN DETAIL IN FIG. 3, IS A SMALLER UNIT, EMPLOYING RECOVERY OF THE EVOLVED HYDROGEN-DEUTERIUM MIXTURES AND USED FOR MORE CONCENTRATED SOLUTIONS. THE COPPER STILL FOR DISTILLATION OF ALKALINE LIQUORS IS SHOWN AT C.

C_2H_2, and acetone, CH_3COCH_3, do not replace their hydrogens for deuterium in acid solutions or in plain heavy water but do so more or less readily in basic solutions. The former exchange indicates definitely the acidic nature of acetylene. The latter demonstrates that acetone in basic solutions exists partially in another form $CH_3 . COH : CH_2$ which is acidic in nature due to the H attached to oxygen. In acetic acid CH_3COOH only the final acidic H is readily replaceable by D. In a compound such as nitroethane, $CH_3CH_2NO_2$, the two hydrogen atoms next to the NO_2 group are replaceable by deuterium in basic solutions of heavy water. In this case the rate of reaction can be measured and it has been shown that H atoms leave this molecule more easily in the heavy water solutions than they do in light water solutions. Similarly, cane sugar is broken up by reaction with heavy water faster than by light water. In other reactions the velocity is slower in heavy water. The accelerating or retarding effect obtained is used by the chemist to decide the detailed picture of what is occurring in such solutions. With deuterium atoms as labelled hydrogen atoms, much can be learned about these detailed occurrences; and what is found for deuterium must also occur with hydrogen under the same conditions,

even though, without the label, this can not be demonstrated. Reactions of deuterium and deuterium compounds which are slower than those of hydrogen are due to the fact that the lowest energy states (the zero-point energies) of the former are less than those of the latter. To become equally activated, by heat or light, deuterium must receive greater increments of energy; *vice versa,* under equal energy conditions the deuterium compounds will in general be less reactive. In cases where this does not hold it is to be concluded that reaction does not involve molecules of the deuterium compound, but rather an atom or an ion. Comparative velocity measurements are, therefore, of great importance theoretically.

In the physics laboratory deuterium is being put to spectacular use as a projectile in atomic transmutation. Immediately after the isolation of deuterium the nuclei or deutons were so employed to bombard lithium, the results showing them to be much more effective missiles than protons. Two processes are possible with the isotopes of lithium of masses 6 and 7.

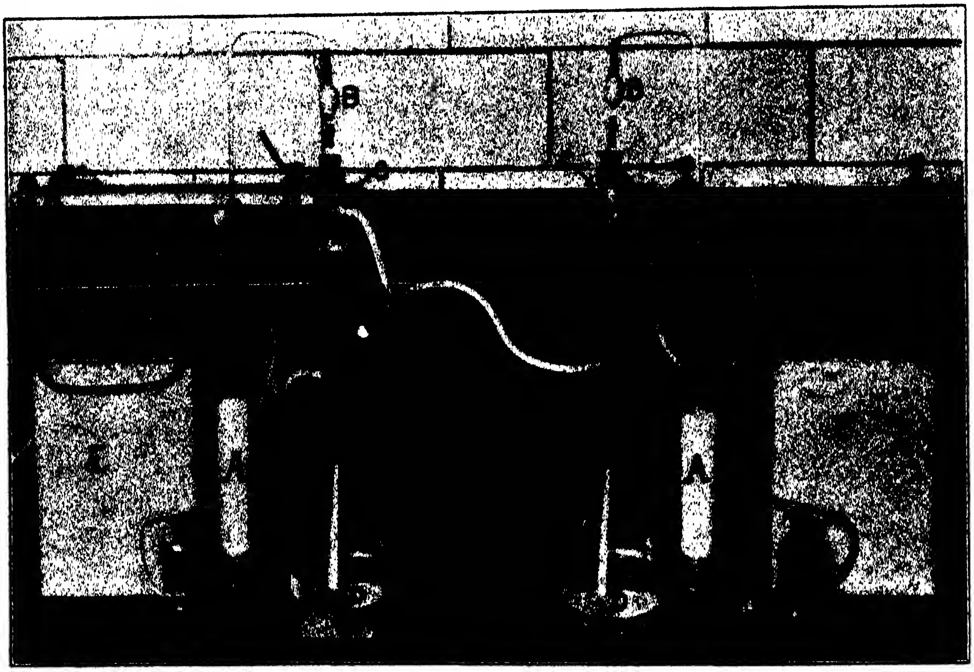


FIG. 3. ELECTROLYSIS WITH RECOVERY OF HYDROGEN-DEUTERIUM AND OXYGEN BY COMBUSTION AND CONDENSATION.

THE HYDROGEN-DEUTERIUM AND OXYGEN ARE FREED FROM SPRAY IN THE TOWERS A CONTAINING ABSORBENT COTTON, PASS THROUGH THE EXPLOSION TRAPS B AND ARE BURNED AT A PYREX JET C. THE WATER IS CONDENSED AND COLLECTED IN D, THE ENRICHED RESIDUE REMAINING IN THE ELECTROLYSIS VESSELS WATER-COOLED IN TANK E.

$$_3Li^6 + {}_1D^2 = 2\,{}_2He^4$$
$$_3Li^7 + {}_1D^2 = 2\,{}_2He^4 + {}_0n^1$$

The subscript to the left represents the nuclear charge; the superscript is the mass. Here also $_0n^1$ represents a neutron of zero charge and unit mass. Helium of mass 4 and charge 2 is the other product.

Experiments in Cambridge under Lord Rutherford suggested that deutons could be used to bombard deutons and

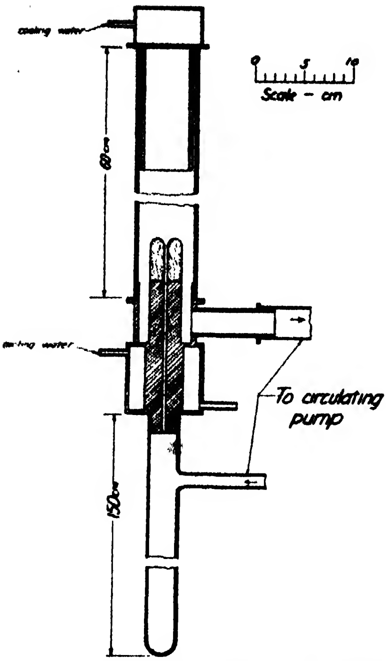


FIG. 4. DIAGRAMMATIC SKETCH OF TRANSMUTATION TUBE. DEUTERIUM IN THE UPPER HALF IS IONIZED AND THE DEUTONS ARE LED THROUGH THE SLIT OR CANAL, BETWEEN THE SHADED AREAS, TO THE LOWER HALF OF THE TUBE IN WHICH THEY COLLIDE, UNDER HIGH POTENTIAL, WITH DEUTERIUM ATOMS AND MOLECULES TO GIVE THE OBSERVED TRANSMUTATIONS TO TRITIUM AND TO HELIUM 3. THE GAS IS CONSTANTLY CIRCULATED BETWEEN THE UPPER AND LOWER HALVES OF THE CANAL RAY TUBE.

produce new forms of matter. Here, also, there are two possibilities.

$$_1D^2 + {}_1D^2 = {}_1T^3 + {}_1H^1$$
$$_1D^2 + {}_1D^2 = {}_2He^3 + {}_0n^1$$

In the first, transmutation gives two hydrogen atoms, one of mass 1, the other of mass 3, in other words, tritium. In the second, the change is to a helium isotope of mass 3 and charge 2 and a neutron of mass 1 and zero charge. Both of these changes have now been decisively demonstrated not only by the methods of Rutherford involving measurements of the tracks of particles; they have been employed to produce these rare isotopes "in quantity." Samples of deuterium after subjection to such atomic bombardment in apparatus shown in Figs. 4 and 5 have been found by the Princeton physicists to contain concentrations of tritium forty times greater than that of the deuterium initially. Similarly, the production of helium isotope of mass 3 has also been shown. In each case the method of analysis involves the sensitive mass spectrograph already discussed. Deutons also are being used as the projectiles for the production of artificially radioactive light atoms, the new field of physics developed only this last year by M.

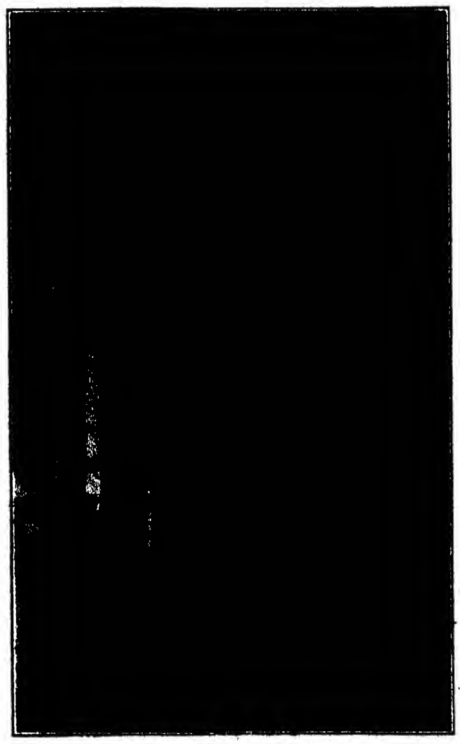


FIG. 5. GENERAL VIEW OF APPARATUS EMPLOYED IN PALMER PHYSICAL LABORATORY, PRINCETON UNIVERSITY, FOR TRANSMUTATION OF DEUTERIUM INTO (a) TRITIUM AND HYDROGEN, (b) HELIUM OF MASS 3 AND NEUTRONS. THE LONG GLASS TUBE SHOWN TO THE LEFT OF THE CENTER OF THE PHOTOGRAPH IS THE ACTUAL LOCATION OF THE TRANSMUTATION PROCESS. THIS UNIT IS SHOWN DIAGRAMMATICALLY IN FIG. 4.

Joliot and his wife, Mme. Curie Joliot, first with alpha particles, next with protons and neutrons and now also with deutons.

That the pace of this scientific development is prodigious all must realize when they remember that only one year ago the deuterium isotope was not yet isolated. To-day it has a still rarer brother, tritium; it has itself given rise to this and to other new isotopes, some radioactive, some not; it has made possible a new branch of chemistry, the chemistry of isotopes which already has markedly enriched our knowledge of general and physical chemistry; it is a potent weapon of attack also on physiological and biological problems.

CALENDAR REVISION AGAIN

By JOSEF J. JOHNSON
DEPARTMENT OF ASTROPHYSICS, CALIFORNIA INSTITUTE OF TECHNOLOGY

Many are the recognized defects of our present Gregorian calendar. Many are the suggestions which have been advanced to correct those defects and to provide a calendar which will meet modern needs as efficiently as possible. Yet comparatively little progress has been made toward the acceptance of a revised calendar, perhaps partly because of the inherent shortcomings of the various systems proposed and because of a peculiarly even balancing of these shortcomings as between rival systems. It is believed that the system here proposed, while by no means free from objections, will at least point a way out of the impasse which has arisen.

The history of the Gregorian calendar, its principal defects, the leap-year rule and the merits and shortcomings of the various proposed revisions have been so ably discussed in a recent article[1] by H. W. Bearce, of the Bureau of Standards, that it would be quite amiss to go into such matters here. Let it suffice to recall that the proposed revisions fall into two groups—the 13-equal-months plan and the 12-month-equal-quarters plan. The former, sometimes known as the "International Fixed Calendar," requires the intercalation of an extra month, for which the name "Sol" has been suggested. It has the obvious advantage of having all months alike; all evenly divisible into weeks. The latter plan, variously known as the "Swiss Plan" and the "World Calendar," lacks the advantages of the former but has the very real advantage of making the year easily divisible into equal quarters. Since the number of days in a year is not evenly divisible by seven, both plans require the insertion of occasional extra days, such as "blank days," "year days," "leap days" or double days—48-hour periods designated as one day and date.

There is some objection, principally on religious grounds, to the insertion of an extra day and the consequent interruption of the regular succession of the seven days of the week. But, as Mr. Bearce has pointed out, this objection must arise against any plan such that all years will begin on the same day of the week. If the objection is sustained, the case for calendar revision is hopeless. If it can be overcome, why not "go whole hog" and definitely part company with the seven-day week? Certainly, if the time was ever ripe for such a change,

[1] Henry W. Bearce, "The Proposed Revision of the Gregorian Calendar," Scientific Monthly, 35: 500, 1932. For an able presentation of the merits of the 13-months calendar, see M. N. Stiles, "The Need for a Thirteenth Month," Scientific Monthly, 39: 151, 1934.

it is ripe now. People who are accustoming themselves to a drastic revision in the length of the working week should be far less startled than as of old by the idea of a change in the calendar week.

Once we give up the seven-day week, our task is greatly simplified and many possible plans suggest themselves. The following is tentatively offered as a fixed calendar for every month of a 12-month year:

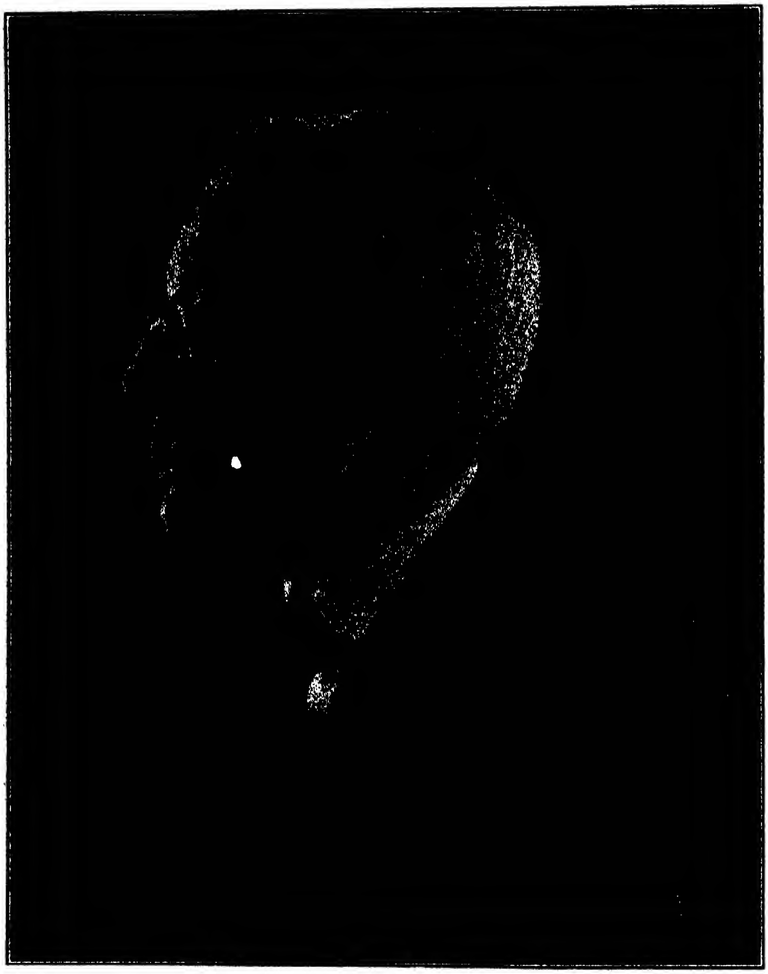
Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
1	2	3	4	5	6	
7	8	9	10	11	12	
13	14	15	16	17	18	
19	20	21	22	23	24	
25	26	27	28	29	30	31*

* Saturday the 31st to be counted in January, March, May, July and September of ordinary years; also in November of leap years.

The above system partakes of all the advantages of the "World Calendar," particularly of the divisibility of the year into halves and quarters—a point of great practical importance for statistical comparisons and computation of interest. It partakes also of the principal advantage of the "International" plan, namely, that, for every month, a given date falls always on the same day of the week. The months are, to be sure, not of exactly equal length; but it is to be pointed out that the apparent equality under the "International" plan is achieved only by means of the subterfuge of putting in an occasional day which does not belong to any month.

It will at once be objected that the plan here proposed would stand no chance whatever of being adopted; that the complete abandonment of the seven-day week is an idea far too drastic ever to be considered by the tradition-bound and custom-loving peoples of the earth.

Not so long ago the validity and finality of such an objection could not have been questioned. But many things have happened during the last few years—witness America's abandonment of the gold standard, the repeal of prohibition, the ———. The age of miracles is still with us. Why not a New Deal Calendar?



Charles W. Eliot

1834–1924

THE PROGRESS OF SCIENCE

AN APPRECIATION OF CHARLES WILLIAM ELIOT

President Eliot of Harvard University was always a commanding figure, a center of attention, in any company of which he was a part. The fact that such a personality was still living, active in mind and body, capable of making an appropriate impromptu speech, at the celebration of his ninetieth birthday, March 20, 1924, lent to that occasion a dramatic interest which the recent centenary observance of his birth could not have in the same degree. But for that very reason the centenary offered perhaps an even better opportunity than the previous anniversary for a just estimate of the man and of his work.

He was an inheritor of the best New England qualities and traditions. He was energetic, practical and purposeful, capable of success in any business undertaking which might have attracted him. At the same time he was a moral idealist, a sincere Puritan, though without a trace of bigotry. He was a philanthropist who studied how to bring out the best possibilities in every individual whom his influence could reach. He was a deeply religious man, in faith and in feeling rather than in acceptance of dogma, and his devotion to the chief undertakings of his life was essentially a religious devotion.

Closely akin to his religious faith was his faith in human nature, his trust in the capacity, mental and moral, of the ordinary individual when properly appealed to. This had much to do with his famous predilection for the "elective system," almost free choice, for the individual college student among a great variety of courses offered. Admitting that some students would misuse this freedom, as some individuals will misuse any freedom, he believed this evil to be outweighed by the opportunity given for voluntary development of one's own best faculties and by the strengthening of character which the responsibilities of self-direction give.

If I had to characterize by a single word his conception of what education should be, I should choose the word *vital.* Teachers, he said in his inaugural address, should be young men or the kind of men who do not grow old. Education must be a quickening influence. It should bring the student into contact, the more intimate the better, with facts that interest him, that excite his curiosity, that cultivate his powers of observation and reasoning, that equip him for an active, useful and self-respecting career. Nothing should be taught or learned year after year merely because it had been taught or learned year after year. Moreover, education for any specific calling should be thorough. No man should enter the practise of any profession until he is as well qualified for that profession as he can reasonably be qualified for it by institutional training.

These propositions may seem commonplace now, but they were not commonplace sixty-five years ago, when Eliot became president of Harvard. If they are commonplace in America to-day, it is largely because his faith, his persistency, his power as a leader have made them so.

His leadership, contrary to the opinion which used to be rather prevalent among those who did not know him well, was not of the imperious kind. He sought always to persuade, not to subdue, or to repress discussion. He was proverbially a good listener, and it was partly for this reason, no doubt, that he was proverbially a good judge of the character and capacity of individual men. He had a large measure of freedom in the appointment of members of the various Harvard faculties, especially, perhaps, the Faculty of Arts and

Sciences, and he made appointments with much care, though not with a view to securing support for his own opinions. I once heard him say that one of the chief qualifications of a college president is the ability to recognize "the natural teacher and the real gentleman, sometimes under considerable disguises." The last four words of this quotation, saving the statement from being too flattering to a faculty audience, are, by the way, an excellent example of the always effective and always dignified humor with which his speeches and conversation were occasionally lightened.

In one of his informal addresses to undergraduates he said, in describing what traits distinguish a gentleman, "A real gentleman will always be considerate toward those whom he employs, toward those who might be considered his inferiors, or who are in any way in his power." As president he acted in accordance with this rule, but nevertheless an interview with him on a matter of business was for most members of the Harvard faculties something of an ordeal, as the following lines written by a professor many years ago will indicate:

> Don't be nervous, he will give you
> no unnecessary pain,
> As he deftly takes your cranium off
> and looks into your brain.

Such being the man, his aims and his methods, his work was fruitful. He maintained direct and active contact with every faculty of the university. By appointing more well-chosen teachers, by offering new courses, by extending the elective system, by infusing the whole with his own invigorating influence, he made of Harvard College a new institution, where men of learning and ability were glad to do their life work and where students gathered in increasing numbers. He recognized Langdell as the prophet of a new era in the teaching of law and placed him at the head of the Law Faculty, with results now known and acclaimed throughout the English-speaking world. In the Medical School, where shamefully loose and superficial methods of instruction had prevailed, he insisted upon, and against great opposition secured, a course of instruction and training commensurate with the responsibilities of the medical profession. The now famous Harvard School of Business Administration was founded in the later years of his presidency. In short, taking command of Harvard when the elder Agassiz, trained in Europe, declared it to be hardly worthy of the name university, he, in the course of forty years, made it one of the great institutions of learning in the world.

But he did more than this. He was public-spirited in the broadest way. He was actively interested in the primary and secondary schools of the country, and he exerted in various ways a stimulating influence upon them. His time, his thought, his experience were at the service of any college head who asked his advice, as many did.

He took an active part in the discussion of social and political questions, though he never had any political office and twice declined an offer of the London ambassadorship. Especially in his old age, after his retirement from the presidency of Harvard, he held a unique place as a venerated counselor of the American people.

As a speaker, whether in private or in public, President Eliot was remarkably effective. In look and manner he was quietly imposing, and in his later years benignant. His voice was at the same time mellow and powerful, always carrying and never seeming loud. He seldom indulged in flowers of rhetoric. He always seemed to be thinking his way along as he spoke, though he never hesitated, never needed to revise his sentences before publication. He once said, on the question of what constitutes a liberal education, that the only indis-

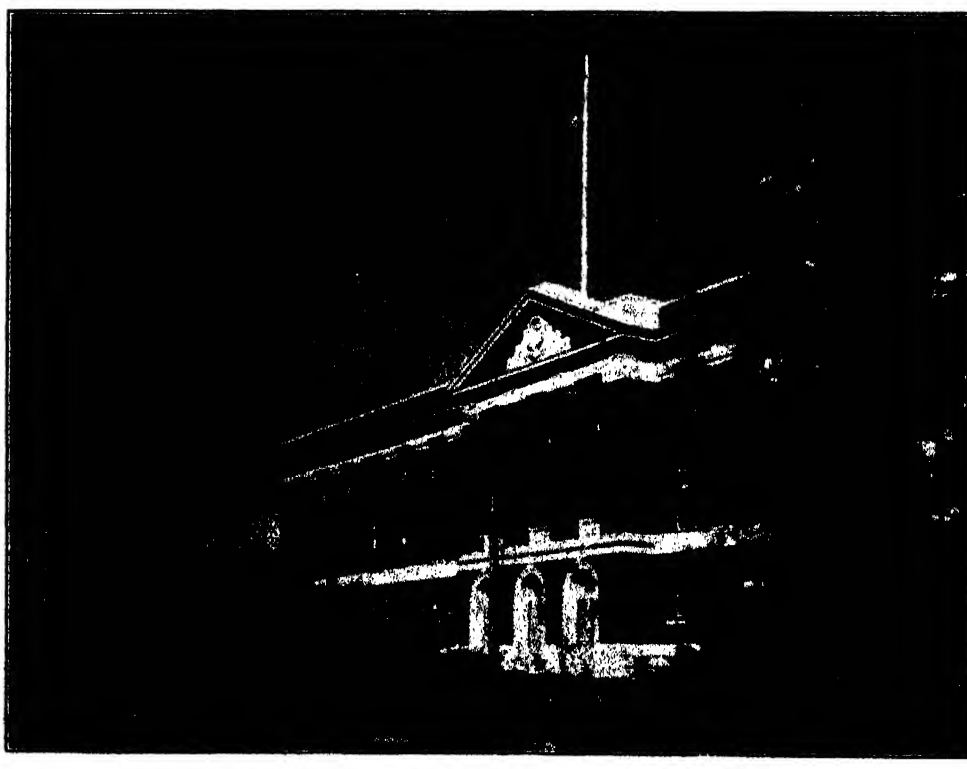
pensable requisite is a mastery of one's own language. This mastery he had, both in form and in substance, though he did not possess and he distrusted in others the gift of automatic eloquence.

EDWIN H. HALL

DECENNIAL REVIEW OF THE WORK OF THE MARINE BIOLOGICAL LABORATORY

AT the time of erection of the permanent buildings and of the establishment of the endowment of the Marine Biological Laboratory in 1923, a deed of trust was created, providing for custody of endowment funds; and, also, among other things, for a decennial review of its work. The purpose of these provisions was to ensure the continuation of management in the hands of American biologists, and at the same time to provide for expert administration of endowments. The membership of the Committee of Review provided for in the deed of trust consists of nine members to be nominated one each by the National Academy of Sciences, the National Research Council, the American Association for the Advancement of Science and by the professors in the field of biology of each of the following universities separately: Harvard University, Columbia University, the University of Chicago, Princeton University, Yale University and the University of Pennsylvania. The specific function of the Committee of Review is to ensure permanent protection of the purposes of the trust.

The committee met at the Marine Biological Laboratory on July 21, 1934, and made a study of its work as provided in the deed of trust, as a result of which they rendered a favorable report to the trustee on the work of the institution. Their meeting provides an opportunity



THE FAÇADE OF THE MARINE BIOLOGICAL LABORATORY.

THE TRUSTEES OF THE MARINE BIOLOGICAL LABORATORY AT THEIR ANNUAL MEETING IN AUGUST.

Top Row: M. J. GREENMAN, director of the Wistar Institute; CASWELL GRAVE, professor of zoology, Washington; E. NEWTON HARVEY, professor of physiology, Princeton; W. E. GARREY, professor of physiology, Vanderbilt School of Medicine; W. C. ALLEE, professor of zoology, Chicago; E. R. CLARK, professor of anatomy, Pennsylvania; LAWRASON RIGGS, treasurer of the Marine Biological Laboratory; D. H. TENNENT, professor of biology, Bryn Mawr; ROBERT CHAMBERS, professor of biology, New York University; C. C. SPEIDEL, professor of anatomy, Virginia; G. H. PARKER, professor of zoology, Harvard; FRANZ SCHRADER, professor of zoology, Columbia; H. B. GOODRICH, professor of biology, Wesleyan; B. H. WILLIER, professor of zoology, Rochester. *Bottom Row:* E. G. CONKLIN, emeritus professor of zoology, Princeton; H. H. DONALDSON, professor of neurology, Wistar Institute; W. B. SCOTT, emeritus professor of geology and paleontology, Princeton; CORNELIA M. CLAPP, emeritus professor of zoology, Mount Holyoke; M. H. JACOBS, professor of general physiology, Pennsylvania; F. R. LILLIE, professor of embryology, Chicago; GARY N. CALKINS, professor of zoology, Columbia; A. P. MATHEWS, professor of biochemistry, Cincinnati; W. R. AMBERSON, professor of physiology, Tennessee; CHARLES PACKARD, assistant professor of zoology, Columbia. *Middle Rows:* H. C. BUMPUS, Brown; B. M. DUGGAR, professor of physiological and economic botany, Wisconsin; L. L. WOODRUFF, professor of protozoology, Yale; C. R. STOCKARD, professor of anatomy, Cornell Medical College; R. S. LILLIE, professor of general physiology, Chicago; E. B. WILSON, emeritus professor of zoology, Columbia; T. H. MORGAN, professor of biology, California Institute; R. G. HARRISON, professor of comparative anatomy, Yale; L. V. HEILBRUNN, associate professor of zoology, Pennsylvania; FRANK P. KNOWLTON, professor of physiology, Syracuse College of Medicine.

to present to a wider public some aspects of the work of a unique institution.

It should, then, be recorded that the Marine Biological Laboratory was established at Woods Hole, Massachusetts, in 1888; and that from the start the management of its affairs has rested in the hands of American biologists on a cooperative basis. The members, numbering for many years over 300, elect a board of trustees composed exclusively of scientific men, who are responsible for the management. The high scientific reputation and stable membership of this board has ensured a consistent development of the institution.

The period under review by the special committee includes establishment of the endowment fund, the erection of the main laboratory, the establishment of a special library endowment and the erection of fireproof dormitories. Such events are not likely to be duplicated in the next decennium. They have naturally given a very important impetus to the work of the laboratory, but they have in no way altered its previously existing aims and purposes. During the last four years the general economic distress has been reflected in the laboratory by some reduction of activities; but, on the whole, the work of the laboratory has exhibited marked stability.

The number of investigators increased from 176 in 1923 to 362 in 1931 and fell off to 319 in 1933; the institutions represented by workers were 107 in number in 1923, 137 in 1931 and 120 in 1933. The total number of institutions represented in the decennium was 414, of which 95 were foreign institutions of learning. The development of the library has been very rapid and continuous: in 1923 the library contained 11,698 bound volumes and 9,587 pamphlets; in 1933, 37,420 bound volumes and 81,208 pamphlets. In 1923 journals currently taken numbered 281; and, in 1933, 1,137. A somewhat comparable development of research facilities and apparatus occurred during the same period.

The findings of the Committee of Review were to the following effects: that "the organization of the Laboratory, as embodied in its Constitution and By-laws, continues to operate effectively under the control of professional biologists. The Laboratory is especially well equipped for researches in general biology, experimental zoology and botany, embryology, physiology, biochemistry, biophysics and other branches of the biological sciences. Its research rooms, apparatus and facilities are excellent, and during the summer these are used to capacity. Living material for research is abundant and is promptly supplied by the Collecting (Supply) Department. The library is generally recognized as one of the best biological libraries in the country; it has increased about three-fold during the past decennium. It is freely accessible to investigators and is extensively used. General lectures and conferences are given at least twice a week throughout the summer session. They are largely attended and in general are very instructive and stimulating. One of the most important features of the Laboratory is the close personal association of workers in many fields over considerable periods of time. This is one of the chief attractions of the Marine Biological Laboratory."

The Marine Biological Laboratory serves the needs of all the universities, colleges and biological research institutions of the country, and offers its facilities to foreign institutions. It is a matter of general public interest that this institution, now in its forty-seventh year, through its unique form of organization, preserves all its pristine vigor and enthusiasm, owing to the fact that so many of the rising generation of biologists are drawn into membership. The control of its affairs thus changes

gradually and automatically, and the development of the biological sciences is always reflected in its membership.

The Woods Hole Oceanographic Institution, founded in 1930, has brought into the local scientific community a new strong group of workers, and has greatly increased the breadth of interests. Its location was determined largely by the reputation as a scientific center given to Woods Hole by the work of the Marine Biological Laboratory and the United States Bureau of Fisheries in its station established there since 1885. Mutual advantages accrue to these three institutions by their close association and cooperation.

FRANK R. LILLIE

PREHISTORY IN PALESTINE

PALESTINE'S place in prehistory and history runs parallel with its geographic position as a link in the chain which binds together the three continents of the Old World. Its prominent place in history and proto-history now bids fair to be equaled by its growing importance as a fertile field for prehistoric research. The attention of prehistorians was attracted to the Near East by Zumoffin's researches in caves on the Syrian coast near Beirut (1897); little was done, however, within the present limits of Palestine until after the World War. During the past dozen years much has been accomplished through educational institutions centered in Jerusalem in cooperation with and encouraged by the department of antiquities.

With Palestine as one of its prospective fields of operation, the American School of Prehistoric Research was founded in 1921. Our first opportunity to do some reconnaissance in Palestine came on the occasion of the International Congress of Archeology held in Jerusalem and Beirut in April, 1926. Prospecting at a number of prehistoric sites and examination of museum collections confirmed us in our previous estimate of the prehistoric possibilities of Palestine.

Exploitation of stone at the base of an escarpment in the Wady al-Mughara near the foot of Mount Carmel in 1928 accidentally brought to light two rare prehistoric carvings in bone. The site is less than six kilometers southeast of the Crusaders' Castle at Athlit (some 19 km south of Haifa). The discovery was reported to the Department of Antiquities, then referred to the British School of Archeology in Jerusalem. Miss Dorothy A. E. Garrod, representing the British School, then invited our school to join in the work of exploring and excavating that which turned out to be a group of caves, three of which have proved to be extremely important. The three productive caves are Mugharet el-Wad (Cave of the Valley), where the accidental discovery had been made, Mugharet es-Skhūl (Cave of the Kids), and Mugharet et-Tabūn (Cave of the Oven). The first two caves have already been completely excavated. The seventh season of excavations is now in progress and will complete the excavation of the third cave (Tabūn).

The sequence of cultures in the Mugharet el-Wad is remarkable for its completeness; the series, beginning at the top, is as follows: (A) Bronze Age to Recent; (B1) Upper Natufian (Mesolithic); (B2) Lower Natufian; (C) Upper Aurignacian of Caspian (African) affinities; (D) Middle Aurignacian; (E) Lower Middle Aurignacian; (F) Layer of erosion, containing both Aurignacian and Mousterian; (G) Upper Mousterian.

Many human skeletons were found in the two Natufian layers; numerous beads of dentalia shells and perforated animal teeth were found with some of these skeletons (Fig. 1). The Natufian deposits also yielded carved bone haftings set with microlithic flints (Fig. 8).

FIG. 1. HUMAN SKELETON
WITH CIRCLETS OF DENTALIA SHELLS ABOUT THE CRANIUM. MUGHARET EL-WAD.
LOWER NATUFIAN EPOCH.

These were obviously used as sickle blades in the harvesting of grain. It seems therefore that agriculture had its beginnings as far back as the Natufian and antedates the potter's art; for no pottery has been found in Natufian deposits.

The Mugharet es-Skhūl deposit is of Lower Mousterian age. Theodore D. McCown of our school was in charge of its excavations. It was here that he found nine Neanderthal skeletons, the largest number ever found at a single site anywhere in the world. They were embedded in a breccia so hard that, in order to remove a single skeleton, it was in some cases necessary to cut out a block of stone weighing a ton. These blocks were sent to the Royal College of Surgeons, London, where McCown has been since last September superintending the extraction of the skeletons from the stone. The work is tedious and costly, but is facilitated through the use of an electro-pneumatic chisel and an electric dental lathe. The work of preparing these skeletons is still far from complete. The expense is being borne jointly by our school and the Royal College of Surgeons. The school's share of the cost is met through a generous grant from the American Council of Learned Societies. The University of California is contributing indirectly to the joint undertaking by awarding a fellowship to McCown.

The nine skeletons from the Mugharet es-Skhūl all belong to an early type of the Neanderthal race and furnish skeletal parts, which were missing in Neanderthal skeletons found previously in other parts of the world. The full sig-

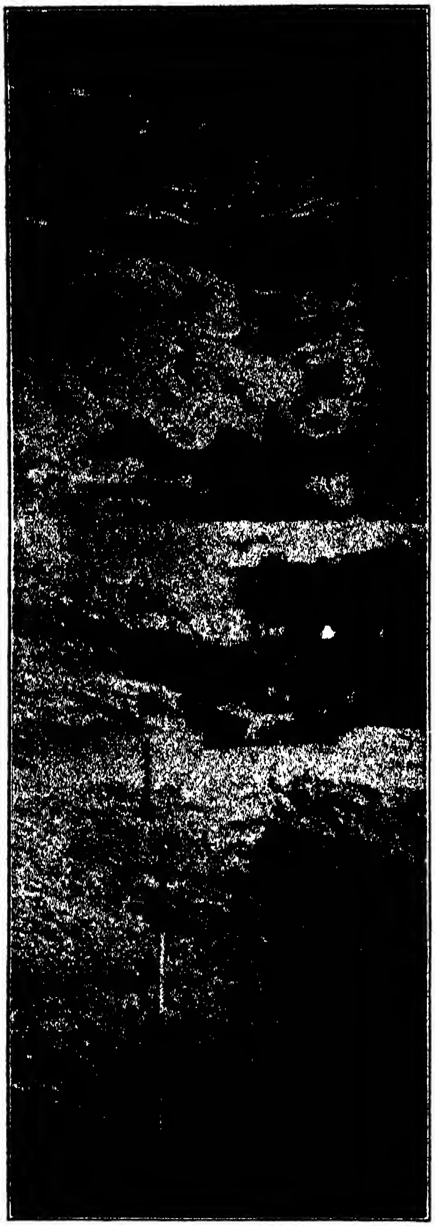


FIG. 2. CROSS SECTION OF CAVE

INTERIOR OF MUGHARET ET-TABŪN (CAVE OF THE OVEN). ALL THE LAYERS ARE VISIBLE EXCEPT: A (BRONZE AGE TO RECENT), AT THE TOP; AND E (ACHEULIO-MOUSTERIAN) AND F AND G (ACHEULIAN AND TAYACIAN) AT THE BOTTOM.

nificance of this rich harvest from a single cave can only come to light after the bones have been disengaged from the rock, in which they were found. However, it is already obvious that the Neanderthalians of Palestine differed in several respects from those of western Europe.

The relic-bearing deposits in the Mugharet et-Tabūn are thicker and more ex-

FIG. 3. FRONTAL BONE OF CRANIUM FROM LAYER C, TABŪN CAVE: (a) NORMA LATERALIS; (b) NORMA FRONTALIS.

tensive than are those in the other two caves, and man lived for a much longer period of time at Tabūn. Layer A at the top contains potsherds, which range from Early Bronze Age down to modern Arab. Mixed with these are a small number of Natufian flints. Below this come in turn: (B) Upper Mousterian, (C) Lower Mousterian, (D) Lower Mousterian, (E) Acheulio-Mousterian, a very thick layer with four distinct culture-bearing levels, (F) Upper Acheulian, and (G) Tayacian (Fig. 2). The deposits have a total thickness of 15

FIG. 4. CHINLESS LOWER JAW

(UPPER)—LOWER JAW FROM LAYER C, TABŪN CAVE, RESEMBLING THOSE FOUND IN THE NEAR-BY CAVE OF SKHŪL. NORMA LATERALIS; (LOWER) —CHINLESS LOWER JAW OF THE SKELETON FROM LAYER C, TABŪN CAVE.

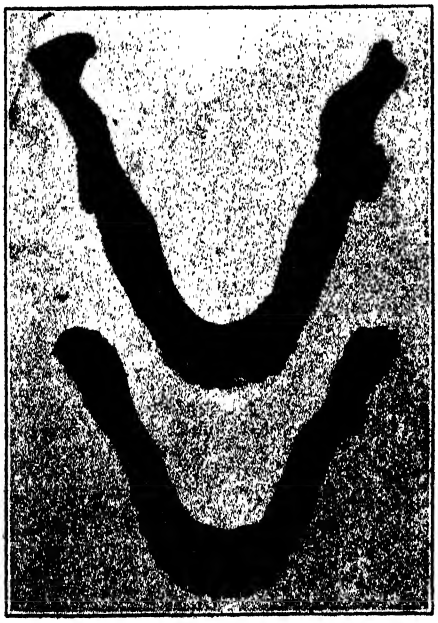


FIG. 5. LOWER JAWS

THE TWO LOWER JAWS FROM LAYER C, TABŪN CAVE. NORMA VERTICALIS.

meters and represent a time period of about 100,000 years.

In the upper portion of Layer C, Miss Garrod found the skeleton of a small adult female, with a low cranial capacity (Fig. 3) and a chinless lower jaw. Some 90 centimeters deeper in the same layer, she found the massive well-preserved lower jaw of an adult male, resembling the lower jaws of the skeletons found by McCown in the Skhūl cave (Figs. 4 and 5). In all these the chin is better developed than is usual among known Neanderthalians. There is also

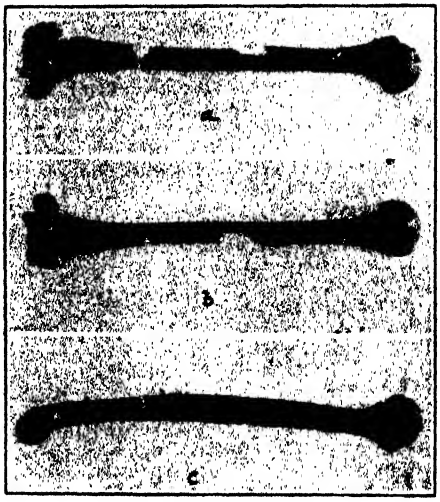


FIG. 6. ARM BONE

LEFT UPPER ARM BONE (HUMERUS) OF THE SKELETON FROM LAYER C, TABŪN CAVE: (a) POSTERIOR ASPECT; (b) ANTERIOR ASPECT; (c) VIEW OF THE SIDE NEAREST THE BODY.

a difference between the limb bones of the Tabūn skeleton and the limb bones of those from Skhūl (Fig. 6). These differences represent extreme variations within the same race, combined of course with individual and sex variations.

Miss Garrod has prepared a composite section of the three caves in the Wady al Mughara (Fig. 7). It shows at a glance the absolute and relative thickness of the layers found in each of the caves, as well as how these layers overlap. The combined thickness, not counting repetitions, is 21 meters. In addi-

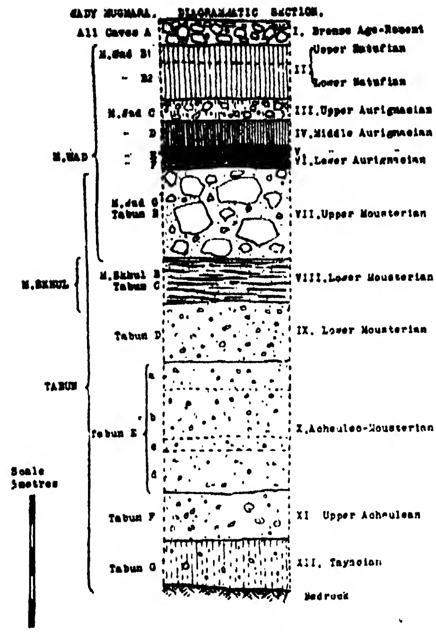


FIG. 7. CHART OF CAVE

COMPOSITE SECTION OF THE THREE WADY AL-MUGHARA CAVES; IT REPRESENTS A PERIOD OF AT LEAST 100,000 YEARS AND ITS THICKNESS, NOT COUNTING DUPLICATIONS OF LAYERS, IS MORE THAN 21 METERS.

tion to the record-breaking list of human skeletons, these various layers also yielded a rich harvest of cultural remains.

Our American School has likewise combined with the British School in the partial excavation of the Mugharet el-Kebara, near Zichron Jacob, some 16 kilometers south of Wady al-Mughara. As far as the excavation went (to the Lower Middle Aurignacian), the section revealed is not unlike that of the Mugharet el-Wad. The underlying deposit, not yet excavated, seems to be Mousterian. The most interesting layer is the Lower Natufian, corresponding to B2 of the Mugharet el-Wad. It yielded an abundance of bone implements, including very delicate harpoons with a single row of barbs and a splendid series of bone carvings, two of which are on the end of sickle blade hafts (Fig. 8). They are in the same class, only more complete, as these found in the Mugharet el-Wad. Mr. Turville-Petre, assisted by Mrs. Baynes, was in charge of the work in the Kebara cave.

A temporary exhibition of the results of the joint Palestine expeditions was held from February 1 to May 1, of this year, at the British Museum, through the courtesy of the trustees of the museum and the cooperation of Reginald Smith, keeper of the Department of British and Medieval Antiquities, and

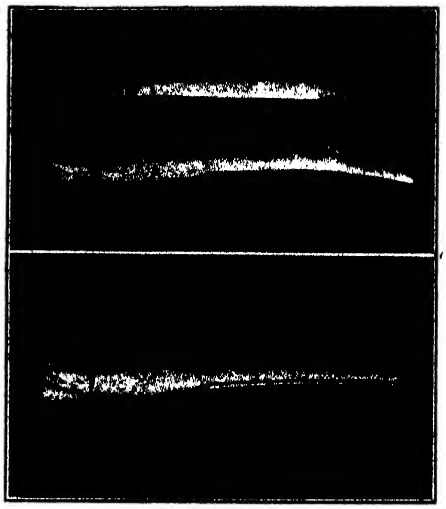


FIG. 8. SICKLE BLADES

TWO CARVED BONE HAFTINGS FOR SICKLE BLADES, COMPLETE EXCEPT FOR THE MICROLITHIC FLINTS, WHICH WERE SET IN THE LONGITUDINAL GROOVE SEEN IN THE FIGURE AT THE BOTTOM. MUGHARET EL-KEBARA. LOWER NATUFIAN EPOCH.

T. D. Kendrick and Christopher Hawkes, assistant keepers. Miss Garrod and Mr. McCown arranged the exhibition so as to include: (1) a complete sequence of the cultural remains from the Tayacian to the Natufian; (2) various animal bones from the different layers; and (3) some of the Neanderthal and Natufian (Mesolithic) skeletons.

GEORGE GRANT MACCURDY,
Director

AMERICAN SCHOOL OF
PREHISTORIC RESEARCH
YALE UNIVERSITY

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SOIL EROSION—A NATIONAL MENACE

By H. H. BENNETT

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UNRESTRAINED soil erosion is rapidly building in this country an empire of worn-out land. The cost of this evil to our farmers and ranchers amounts to at least $400,000,000 annually, to say nothing of the enormous damage to highways and railways and the costly silting of reservoirs, streams and ditches. This appalling wastage is speeding up with the washing off and blowing off of the absorptive topsoil, down to less absorptive, less productive, more erosive subsoil. Over this erosion-exposed material, usually consisting of comparatively impervious clay, rainwater flows away faster from millions of denuded acres to increase the frequency and volume of floods.

At least three billion tons of soil material are washed out of the fields and pastures of America every year. To load and haul away this incomprehensible bulk of rich farm soil would require a train of freight cars long enough to encircle the earth thirty-seven times at the equator. More than four hundred million tons of solid matter are dumped into the Gulf of Mexico every year by the Mississippi alone, along with many more millions of tons of dissolved substances. These materials come largely from the farms of the Mississippi Basin. The greater part consists of super-soil—soil richer than that of the Nile. But the sediments entering the oceans represent merely a fraction of the soil washed out of fields. The greater part is piled up along lower slopes, where it is not needed, or it is deposited over stream bottoms or laid down in channelways and reservoirs. Once the soil leaves a field, it is as irretrievably lost as if consumed with fire, in so far as pertaining to the field from which it is washed. It can not be economically hauled back, even that which is temporarily lodged not far down the slope.

Thousands of farmers operating on slopes stripped of the more productive surface layer have but the slimmest opportunity to make a satisfactory living, whether prices are up or down. They have been lowered to the discouraging level of cultivating land whose productivity has been reduced from two to ten times or more by this tragic wastage, most of which could have been prevented. We find them, generally, not along the main highways, but in the back country, housed in miserable dwellings and living pitifully inadequate lives, with their system of cultivating little plots of ground scattered between gullies and abandoned fields.

WHOLESALE LAND WRECKAGE

Already, the nation has permitted the essential destruction of an area of formerly cultivated land that exceeds the combined extent of Illinois, Massachu-

setts and Connecticut. This is the equivalent of about 220,000 farms of 160 acres each. In addition, this washing of sloping fields has stripped off all or the greater part of the productive topsoil from 125 million acres of the land at present in cultivation; and now, wind erosion is rapidly developing other enormous areas of poor land, as well as destroyed land in our semi-arid belts.

Man's activities in subduing the forests of eastern America, then the prairies to the west and finally the plains, valleys, mountains and intermountain basins beyond, have proceeded along lines of reckless land use. So vast were our original resources in land that no one was concerned with matters pertaining to soil conservation. But now the country may as well gird its belt for continuing battle against this process of land wastage, if we are to avoid the ominous eventuality of becoming the world's most outstanding nation of subsoil farming—which means, generally, submarginal farming, with all its attendant evils of poverty, declining social and economic values and a hopeless outlook upon life.

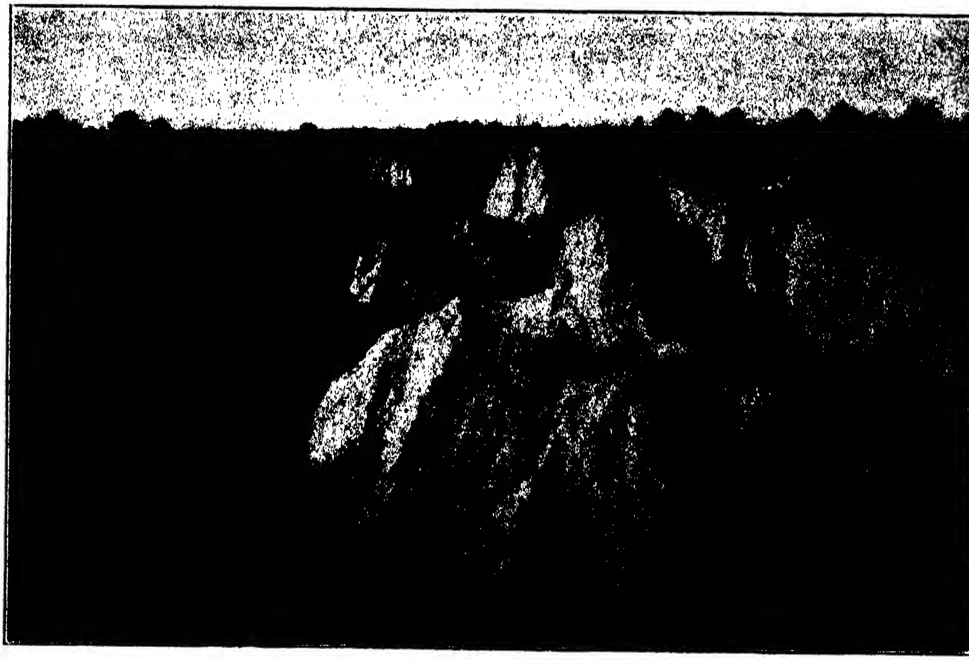
FIRST STEP IN CONTROL OF EROSION

BY SOIL EROSION SERVICE ON THE SOUTH TYGER RIVER PROJECT, SOUTH CAROLINA. FOLLOWING THE INSTALLATION OF THESE CHEAP LOG DAMS, VEGETATION IS SET IN THE GULLIES AND BETWEEN THE GULLIES. SUCH SORE SPOTS MUST BE CONTROLLED IN ORDER TO PROTECT GOOD FARM LAND ON SLOPES BELOW.

A New American Experience

On the eleventh day of May this year the sun was blotted out over a vast area of northeastern United States by a huge dust storm that originated in the drought-stricken wheat fields west of the Mississippi. This "dry blizzard" of sun-obscuring yellow dust, which swept an estimated bulk of three hundred million tons of rich soil from the sun-parched lands of the Great Plains, marked a stage in our system of land use that should alarm and arouse every thinking citizen. It was a thing that never before happened in America, at least, not since the coming of white men. It was a historic event of far more significance with respect to the continuing welfare of the country than most of the incidents included in our histories.

This onward sweeping dust cloud was not the result merely of an unprecedented set of seasonal conditions. For untold centuries droughts have characterized the Great Plains region. The very physical features of the land have been fixed by this climatic factor (the "caliche" or *mid-latitude pedocalic* soils, for example). The wind which



WHAT EVENTUALLY HAPPENS IF GULLIES LIKE THOSE IN THE PHOTOGRAPH ON PAGE 386 ARE NOT CONTROLLED

FORESTED VIRGIN LAND DAMAGED BY GULLIES

THAT STARTED IN AN ADJACENT HIGHER-LYING FIELD. SPARTANBURG COUNTY, SOUTH CAROLINA.

drove that stupendous bulk of soil material half way across the continent was not one which in itself could have accomplished the gigantic task. The real cause was man-induced, speeded-up soil erosion resulting from agricultural utilization of those dry-land areas, plus, of course, a high degree of ground desiccation and soil-lifting winds. Formerly, a natural cover of grass stabilized the ground against wind movement. When this cover was broken, first by farmers venturing beyond the prairies and later by large-scale wheat producers, with their tractors and combines, the loosened soil was laid bare to the driving force of the wind. Its natural firmness was further diminished by continuing cultivation, accompanied by dissipation of the vegetable matter in the soil and the breaking down of the natural structure of the soil—its granularity and fragmental character. Thus, man with his plows and crops developed an incoherent, powdery soil condition favoring the ready lifting of the finer particles into the high pathways of air currents and the leaving of the coarser infertile grains to drift at lower levels by a process of saltation, thus to cover productive land with relatively unproductive wind-assorted material.

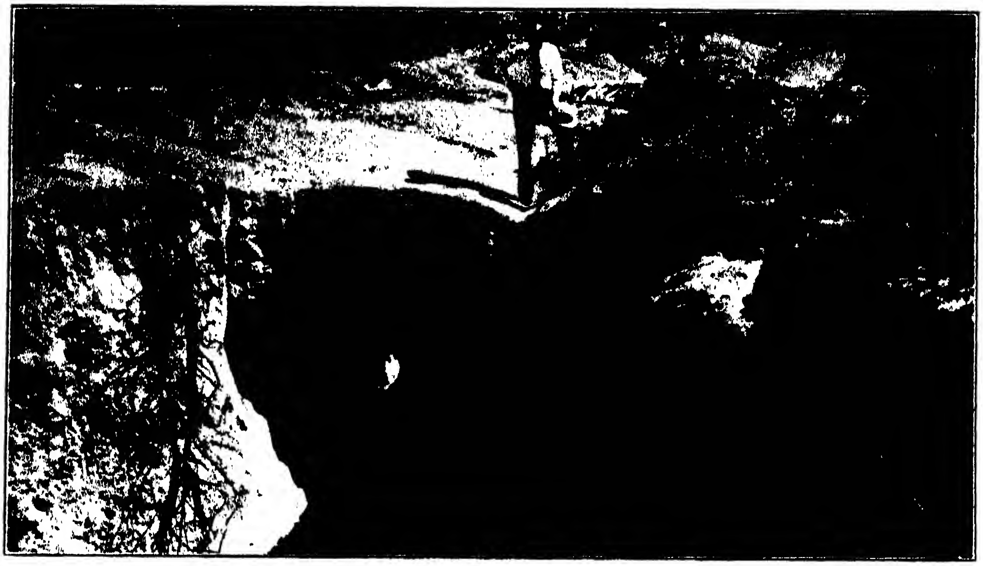
This is the simple physics of the process of land stripping by wind, as it is also, essentially, of the still more powerful soil-transporting force of rainwater. It is not an expression of opinion, but a technically determined fact.

Erosion by Water the Major Evil

Land impoverishment by rainwash is an even more serious economic problem than that of wind erosion. The erosion problem in its entirety is a national problem, the economic gravity of which outstrips any of the temporary worries about which we have heard so much recently. But the nation has not yet realized this fact.

What has happened in Stewart County, Georgia, is an excellent illustration of the destructiveness of man-induced erosion. Approximately one fourth of the area of that county—70,000 acres—has been permanently destroyed by gullying. Originally most of this destroyed area consisted of the

THE ONLY HOPE FOR GULLIED LAND OF THIS KIND IS FORESTRY



UNDERCUTTING TYPE OF GULLY

THE KIND MOST DIFFICULT TO CONTROL. HERE CLAY SOIL IS UNDERLAIN BY SOFT, DECOMPOSED GRANITE WHICH CUTS OUT WITH EVERY HEAVY RAIN CAUSING THE SOIL ABOVE TO CAVE IN. SOUTHERN PIEDMONT REGION.

best farm land in the great coastal plain section of that state. There is no practical means by which these devastated lands can be rehabilitated, and the wastage is marching steadily ahead through the remaining areas of good land, of which there is none too much now.

Some of the gullies have cut to depths of 200 feet. One of these has engulfed a schoolhouse, two farm buildings and a graveyard with 50 graves. Thus, the intermingled débris of wasted land, human habitations and the contents of tombs that were supposed to be the peaceful resting places of man have set out upon a journey of death down the valley of the Chattahoochee River, towards the wastes of the Gulf of Mexico.

The 70,000 acres of land destroyed by erosion in this single Georgia county represent but a fraction of the gigantic stride America has made in the direction of land misuse and consequent land impoverishment and destruction. It is merely an example of the appalling cost of unplanned, haphazard, reckless use of the nation's most indispensable resource—the kind of use that falsely presupposes limitless and inexhaustible supplies of good agricultural land.

Erosion Not a Local Problem

Soil wastage by erosion is by no means restricted to the southern states. It has extended to the shores of California and to the very heart of the great Southwestern grazing region. In southwestern Wisconsin and parts of Iowa, Missouri, Kansas and other central states the rate of soil removal by unrestrained rainwater flowing down across unprotected slopes, has been even faster than in the old sections of the East and South, although not so large an area has been ruined as yet. For example, according to actual measurements, the principal type of corn soil on about the average slope (8 per cent.) of the north Missouri-south Iowa section of the corn belt is losing soil where corn is grown

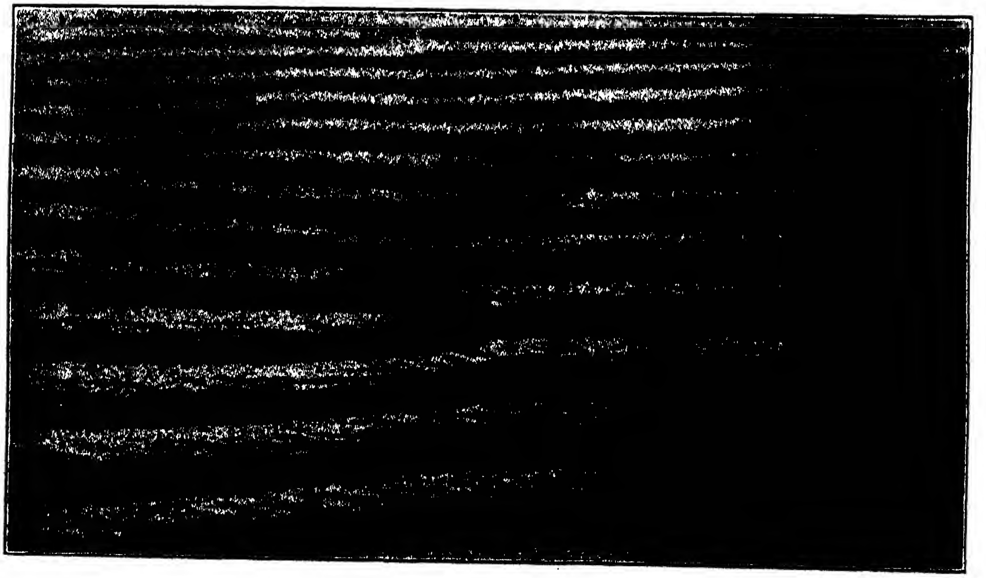
continuously at the destroying rate of 60 tons per acre annually, and with this 27 per cent. of all the rainfall is immediately lost as runoff. This means that the entire depth of the more productive topsoil (about 7 inches) is swept off in approximately 20 years. On the other hand, on exactly the same type of land. occupying the same degree of slope, and receiving the same rainfall, only two fifths of a ton of soil is lost annually per acre where alfalfa is grown and only a little more where timothy grass is grown. The water loss from alfalfa fields is at the rate of only 3 per cent. of the total rainfall. In other words, a thick soil-saving crop like alfalfa is 300 times more effective than a clean-cultivated crop like corn, with respect to conservation of soil. Also alfalfa causes the absorption of 9 times as much of the rainfall as continuous corn.

The average results of measurements made on 12 markedly different and very important agricultural soils, lying largely in the Mississippi Basin, show that grass and similar crops are about 65 times more effective with respect to soil conservation and 5 times more effective with respect to immediate absorption of rainfall than clean-tilled crops grown on the same soils under identically the same conditions as to slope and rainfall.

The Origin of a National Misconception

Immigrants to the American continent found a region so rich in land, timber, grass, game, fish, fur and navigable streams that there early developed in this country a false concept of inexhaustible resources. Unfortunately, this concept has persisted until to-day.

Except in an unimportant way, the Indians had done little to cultivate the soil or to change the virgin character of the land surface and the vegetation on it. The streams bore oceanward the residue of rainwater flowing gently from wooded and grass-covered slopes. Rivers ran clear, except in high flood.



WIND RIPPLES WHICH FORM IN THE DUST PILES FORMED BY WIND EROSION

THE RIPPLES AVERAGE ABOUT 2 INCHES IN HEIGHT AND ARE 4 OR 5 INCHES ACROSS. SOUTH DAKOTA, SUMMER OF 1934.

HOW WIND EROSION AFFECTS A FIELD
SOUTH DAKOTA, SUMMER OF 1934.

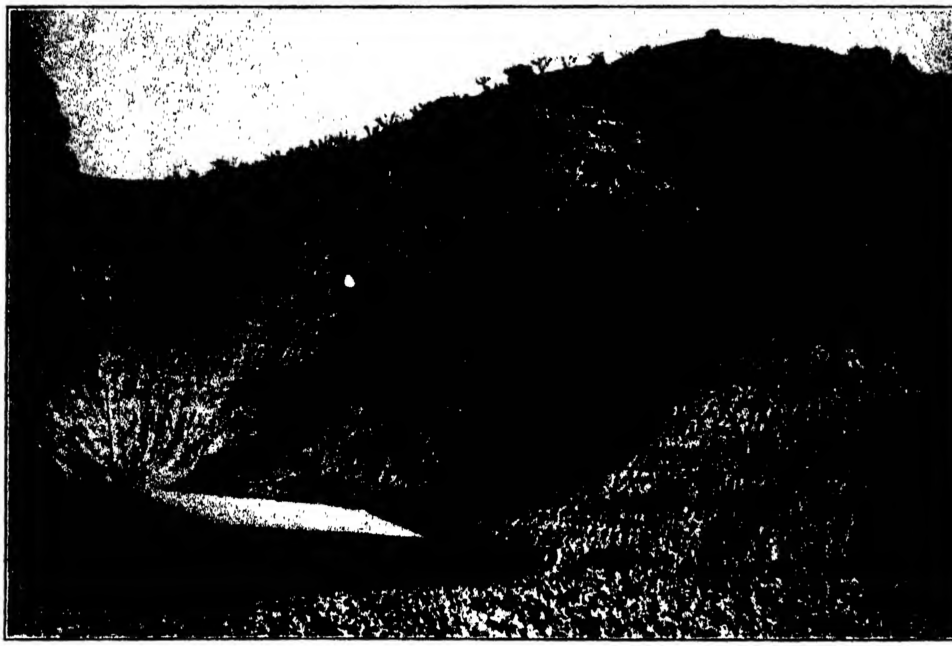
Into this virgin paradise entered the enthusiastic colonists. There began a transformation of the land surface at a rate probably never before occurring in the earth's history, and with it the creation of a nation of fabulous wealth. Reservoirs of population in Europe supplied in a comparatively short time millions of vigorous people to clear away the forests and to break out the prairies in their westward march of agricultural occupation. Frontiers were pushed farther and farther westward at a pace that eliminated planning, or discriminative use of the virgin land, or even thought of the effect of man's activities upon the abundant resources that everywhere swept to far horizons. Man was busy "subduing the wilderness," slaughtering the buffalo for their hides and plowing up the matted sod of the prairies. There seemed no necessity for even thinking of conservation in any form or degree.

Lands which had been thoroughly protected through thousands of years of time by unbroken mantles of vegetation were suddenly exposed over extensive areas to the dash and sweep of torrential rains. Topsoils were literally swept away, leaving raw subsoil exposed at the surface. So stupendous has been the work of this man-induced washing of the land as to reduce and destroy the productivity of millions of acres in numerous densely populated localities within less than a century. The economic and social aspects of this transformation have been tremendous.

Throughout the nation continuing erosion has carried with it consequences of first importance with respect to permanence of investment in the billions of dollars in navigation, power, municipal water supply, irrigation developments, farming and grazing. Products of surface wash and gully excavation have been carried by storm waters to be deposited in stream channels and reservoirs. Yawning gullies have concentrated rainfall in a manner to pass on to streams with greatest possible speed the downpours that gather on watersheds, to gorge the channelways of tributaries and trunk streams with destroying floods. Especially significant is the rapid rate of silting which is going on in reservoirs located on streams within critically eroding areas of the country, both in the East and in the West.

America faces alternatives in this respect. One is to let continue the process now destroying the productivity and utility of millions of acres and adding

annually to a bankrupt domain which is becoming an increasing burden upon counties, states and the Federal Government. Such a way out is not pleasant to contemplate. The other alternative is to diagnose the situation, take full account of the significance and the trend of destructive processes of soil wastage, increasing runoff and sedimentation of reservoirs and stream channels, to relate these to all types of practical land use within drainage basins and to control and reduce these processes to a rate as nearly as may be practicable to the rates that existed when white men found so much of the country covered with unbroken vegetation.



VIOLENT EROSION IN A STEEP, CULTIVATED APRICOT GROVE OF SOUTHERN CALIFORNIA

THE RESULT OF A HEAVY RAIN ON FEBRUARY 23, 1934. THE LOSS OF SOIL PER ACRE AMOUNTED TO 400 TONS. THERE WAS NO EROSION ON THE SAME FARM WHERE LAND OF THE SAME DECLIVITY WAS PROTECTED WITH NATIVE VEGETATION, NOT OVERGRAZED.

At the Crossroads

The nation may as well realize now that it has a land crisis on its hands—the problem of man-accelerated soil erosion, and that every stroke of work performed in opposition to this evil adds value to our most basic resource—that resource which offers the last safe refuge for numerous families thrown out of employment through increased use of machinery, and that resource which after all is the principal security behind our national investments, our national safety and our national future. Beyond this most acute crisis of the whole land problem, the country may as well recognize now the physical fact, not an expression of opinion, that there can be no cure of floods or prevention of stream and reservoir silting until runoff is better controlled, all the way from the crests of ridges down across the watersheds where floods originate and silt loads are picked up, on to the very channelways of streams, which like other conduits have limitations upon their carrying capacity.

Over many millions of acres a long

WIDENING CHANNEL OF PUEBLO COLORADO WASH

INCREASING FLOOD WATER RUSHING DOWN FROM THE DENUDED OVERGRAZED RANGES IS STEADILY CUTTING AWAY THE RICH ALLUVIAL DEPOSITS OF THIS VALLEY, THE FORMATION OF WHICH TOOK THOUSANDS OF YEARS. JUST ABOVE THE TRADING POST OF GANADO, NAVAJO INDIAN RESERVATION, ARIZONA.

FORMER GRAZING LAND

REDUCED TO ESSENTIAL STERILITY BY EROSION FOLLOWING OVERGRAZING, AT SANASTEE, NEW MEXICO, NAVAJO INDIAN RESERVATION. THE SOIL AND SUBSOIL HAVE BEEN WASHED OFF DOWN TO "ALKALI" MATERIAL, ON WHICH IT IS EXTREMELY DIFFICULT TO INDUCE ANYTHING TO GROW.

VEGETATION ON ALLUVIAL SOIL

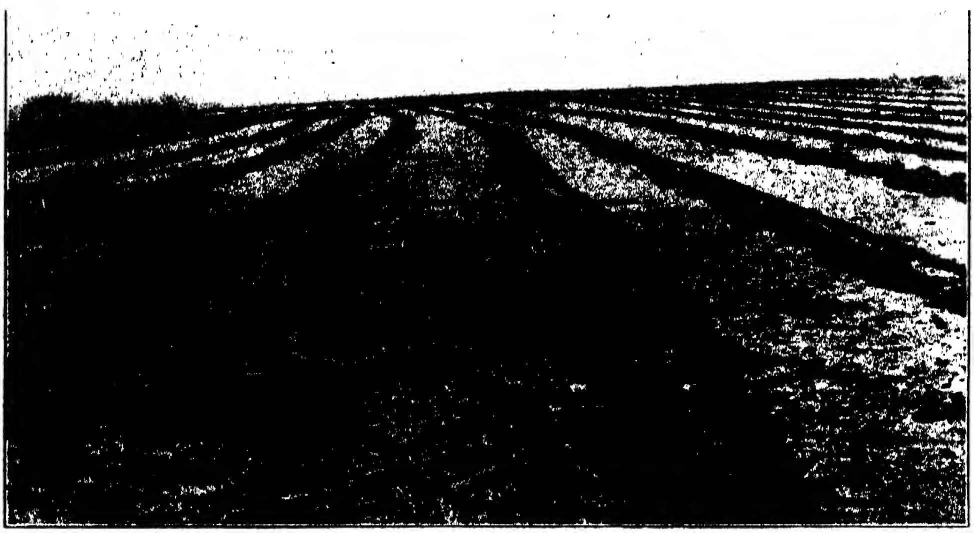
OF A TRIBUTARY TO SAN SIMON WASH, GRAHAM COUNTY, ARIZONA. THIS AREA HAS BEEN PROTECTED AND REPRESENTS AN APPROXIMATION OF THE ORIGINAL CONDITION OF VEGETATION, SUCH AS CHARACTERIZED SAN SIMON VALLEY PRIOR TO THE CUTTING OUT OF THE IMMENSE WASH EXISTING THERE NOW—SINCE THE ARRIVAL OF THE WHITE MAN WITH HIS HERDS OF LIVE STOCK THAT OVERGRAZED THE UPLANDS.

ERODED CONDITION FOLLOWING OVERGRAZING

SAN SIMON VALLEY, GRAHAM COUNTY, ARIZONA. THIS AREA, NOW ESSENTIALLY DESTROYED, WAS FORMERLY COVERED WITH A THICK COVER OF VEGETATION LIKE THAT IN THE UPPER PHOTOGRAPH.

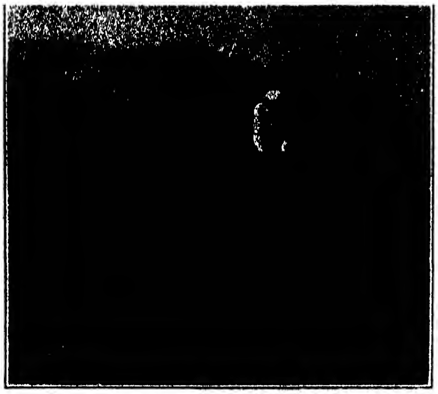
time was required to strip off the highly absorptive topsoil, down to stiff clay of low absorptive capacity; but now that this has been accomplished, and since the surface layer is rapidly being removed from additional millions of acres, the battle is definitely on, and with no secure second lines upon which to fall back.

We have a tremendous area of land in this country, but it is not all good land. Unfortunately, the remaining areas of good agricultural land are being cut into at a rate of probably considerably more than 100,000 acres destroyed every year and a much larger area sorely impoverished by the effects of sheet-washing proceeding with every rain heavy enough to cause water to run down across unprotected cultivated and overgrazed slopes. Most of us have seen the process in action, although without understanding it, and, therefore, without being concerned about it. Few have undertaken to interpret the phenomenon witnessed after every summer rain in the form of muddy waters coursing down gullies, creeks and rivers in the direction of the oceans. We have not stopped to consider that the material discoloring these unleashed waters consists of soil or that this material is derived chiefly from the surface of the ground, where lies the richest part of the land. Probably also most of us have not considered a number of other pertinent matters relating to this never-ending process. Have we considered, for example, the fact that the average depth of humus-charged surface soil over the uplands of the United States is only about seven or eight inches? Have we considered the further fact that beneath this surface layer, the building of which required the best efforts of nature's soil-forming processes over periods of thousands of years, generally lies raw clay subsoil which is not soil but the material from which soil is made, not in a few years but across the centuries? Have we been concerned that this exposed subsoil not only is from two to more than ten times less productive, generally, than was the cor-



CONTOUR FURROWING

TO CHECK EROSION OF OVERGRAZED PASTURE ON SOIL EROSION PROJECT, WATERSHED OF ELM CREEK, CENTRAL TEXAS. PHOTOGRAPHED IN 1934.



RICH BLACK LOAM

AND THE CORN ON IT BURIED 4 FEET DEEP IN PLACES BY SAND WASHED OUT OF A NEARBY GULLY DURING A SINGLE SEASON. ROOT RIVER VALLEY, HOUSTON COUNTY, MINNESOTA.

responding topsoil; that it is more impervious to rainwater, is more difficult and costly to plow, and, what is exceedingly serious, that it is more erosive usually than the sponge-like surface layer? With most of us the answer unfortunately is a very decidedly negative one.

ROCK-FILL DAM

WITH ROCK SAUSAGE CAP CONSTRUCTED BY SOIL EROSION SERVICE IN HAWK HOLLOW WASH, GRAHAM COUNTY, ARIZONA, IN 1934.

Few people (scientist, economist or layman) know that it is at the stage of progressive erosion, marking the removal of the topsoil (the farmers' principal capital) that gullying usually sets in, or that gullying represents the beginning of the death stage of land—its final and complete destruction. This important fact, and many others, the average person knows little about.

Control of Erosion an Unavoidable Necessity

Control of erosion is the first and most essential step in the direction of correct land utilization on something like 75 per cent. of the cultivated (and cultivable) area of the nation. If the soil is permitted to wash to a condition equivalent to skeletonized land, as has happened already over something like 35 million acres formerly cultivated, there will be nothing left to save. Failure to curb this insidious process will effectively and disastrously take care of all aspects of the land problem in numerous localities, both physical and economic; and after this deluge of waste, nature, in numerous instances at any rate, can do as good a job as man with the rehabilitation of the hopelessly devastated areas through the instrumentality of whatever vegetation comes in spontaneously.

It seems scarcely necessary to add that whatever our inclinations may be, whatever opinions, conclusions or complexities our round-table, institute and academic discussions may lead us to, here assuredly is a physical job—the job of curbing erosion—that must be performed if the nation is to avoid early arrival at an inconceivably bad land situation. The Union of South Africa has reached this conclusion and is now busily engaged in an attack against the devastating erosion of that country, employing a plan of procedure very much like that developed by the Soil Erosion Service (as described below). The

Italian Government is engaged in an enormous land reclamation and conservation program—the Bonifica Integrale—the cost of which has been estimated at $500,000,000. Japan for many years has been spending many times the value of numerous critically eroding areas in order to protect indispensable valley lands from the silt issuing from such sore spots. The United States can no more afford to neglect any further this gigantic problem of waning soil productivity than South Africa or Japan or Italy, for the very simple reason that we are depleting our farm and grazing lands at a rate probably exceeding that taking place on any other important part of the globe.

Average Crop Yields Not Increasing

Regardless of our highly successful results with breeding more productive strains of crops and the introduction of new and better varieties from the ends of the world; in spite of the improved cultivation performed with more and better machinery, the increased practise of soil-building rotations and the growing of more soil-improving plants, the largely increased use of fertilizers and plant disinfectants; and further, in spite of all the education provided through our agricultural colleges, agricultural societies, clubs and institutes, soil surveys, economic surveys, experimental and extension services, farm journals, the press, thousands of books and millions of bulletins, with frequent prizes for the best producers, *our nation-wide yields have not increased—rather they have decreased in the instances of some of our major crops.* For example, the annual acreage yield of corn for the 10-year period from 1871 to 1880 was 27.04 bushels per acre; whereas, for the 10-year period from 1921 to 1930 the corresponding acreage production was 26.13 bushels, or a reduction of approximately one bushel an acre. That the maximum and minimum yields for single years during the former period were higher, respectively, than the maximum and minimum yields of the latter period indicate that the comparisons are significant.

When it is considered that corn growing has not been pushed onto the marginal and submarginal lands of semi-arid regions upon any extensive scale, and that the crop has not suffered from any

EROSION MONOLITHS

IN PROVIDENCE CAVE, STEWART COUNTY, GEORGIA. THESE LOFTY PINNACLES ARE REMNANTS OF A FORMER HIGHLY PRODUCTIVE COTTON FIELD. THEY STAND IN A GULLY WHICH WAS BEGUN BY THE DRIP FROM THE ROOF OF A BARN, ABOUT FIFTY YEARS AGO. THE GULLY HAS CUT DOWN 200 FEET AND HAS SWALLOWED UP THE BARN, A SCHOOLHOUSE, A GRAVEYARD AND SEVERAL TENANT HOUSES. IN THE COUNTY WHERE THIS PICTURE WAS TAKEN 70,000 ACRES OF LAND, ONCE HIGH-GRADE FARM LAND, HAVE BEEN PERMANENTLY DESTROYED BY UNCONTROLLED EROSION. EVERY ACRE OF THIS COULD HAVE BEEN SAVED.

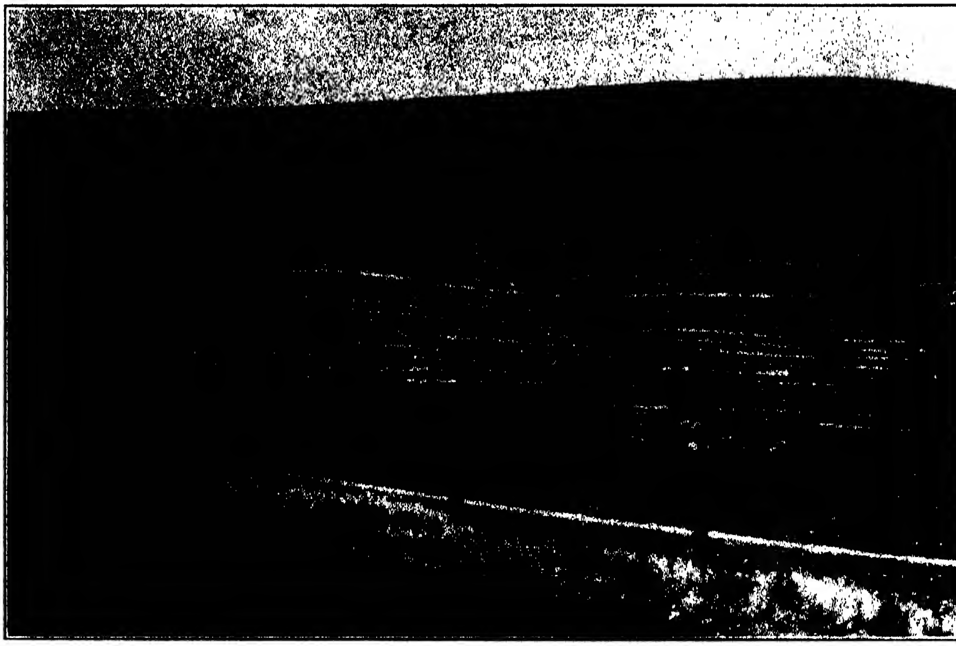
far-reaching, devastating insect or disease scourges, it is impossible to reach any other than the definite conclusion that erosion has thwarted our stupendous technical, educational and practical efforts to increase the yield of this crop.

A Major Effort at Erosion Control

During the latter part of 1933 the Soil Erosion Service was set up as a new branch of the Interior Department, with an allotment of $10,000,000 from Public Works Administration for the purpose of demonstrating the practical possibilities of curbing erosion and its allied evils of increased floods and costly silting of stream channels and reservoirs, operating within the various important geographic and agricultural regions where these evils are known to constitute major problems in connection with the use of the nation's resources of land and water. The general plan of procedure, as suggested by the President, is to treat complete watersheds within which the principal regional types of soil, average regional topographic conditions and representative regional systems of agriculture are found. The individual size of these watersheds, of which 21 are now under treatment in 20 states, ranges from 25,000 to 200,000 acres. The accompanying map shows the location of these watershed areas, and that of the huge project covering the Navajo Indian Reservation in Arizona, New Mexico and Utah; as well as several other projects and proposed projects of an experimental-demonstrational character. Altogether, the Soil Erosion Service is now actively engaged in combatting erosion and its associated evils of stream and reservoir silting, in-

SOIL WASHED DOWN OVER A SNOWBANK

BY THE MELTING OF SNOW ON SUMMER-FALLOWED LAND ABOVE, IN THE PALOUSE REGION, SOUTHEASTERN WASHINGTON.



SEVERE EROSION ON SUMMER-FALLOWED UPPER SLOPE

BY MELTING SNOW, WITH NO EROSION IN OLD WHEAT STUBBLE BELOW, IN THE PALOUSE WHEAT BELT, WASHINGTON STATE, 1934.

creasing floods, social disorganization and wild-life depletion, on approximately 27 million acres located in 27 states.

Plan of Procedure

The method of attack is essentially a coordinated plan of correct land use. This plan involves not only the use of direct methods of retarding erosion (which necessarily calls for retardation of runoff by increasing absorption of the rainfall), but the use of indirect methods, such as the retirement from cultivation of steep, highly erosive areas from which accelerated runoff (resulting from incorrect land usage) descends with destructive effect upon lower-lying cultivated areas. Such retired critically vulnerable lands are being planted with thick soil-holding crops, as trees, grass, alfalfa, lespedeza, sorghum and clover.

Part of the cultivated land is being protected with the new system of strip-cropping, under which the clean-tilled crops, such as cotton, corn and tobacco (the real producers of erosion) are being grown between parallel bands of grass, lespedeza, sorghum and other dense crops planted across the slopes, on the level, *i.e.*, along the contours. These latter crops catch rainwater flowing down the slopes, spread it out and cause the suspended soil to be deposited and much of the water to be absorbed by the ground, thus protecting the crops growing on the plowed strips below. On certain slopes strips of permanent protective cover will be planted according to the French system, using trees, shrubs and vines. Here is an opportunity to make advantageous use of nut trees, persimmon, honey locust (producing feed for livestock), briar crops and other plants of economic value. It is hoped that it may be possible on some of the project areas to employ the Ecuadorian system of protecting steep slopes by bordering the down-hill sides of rectangular fields with soil-holding hedges.

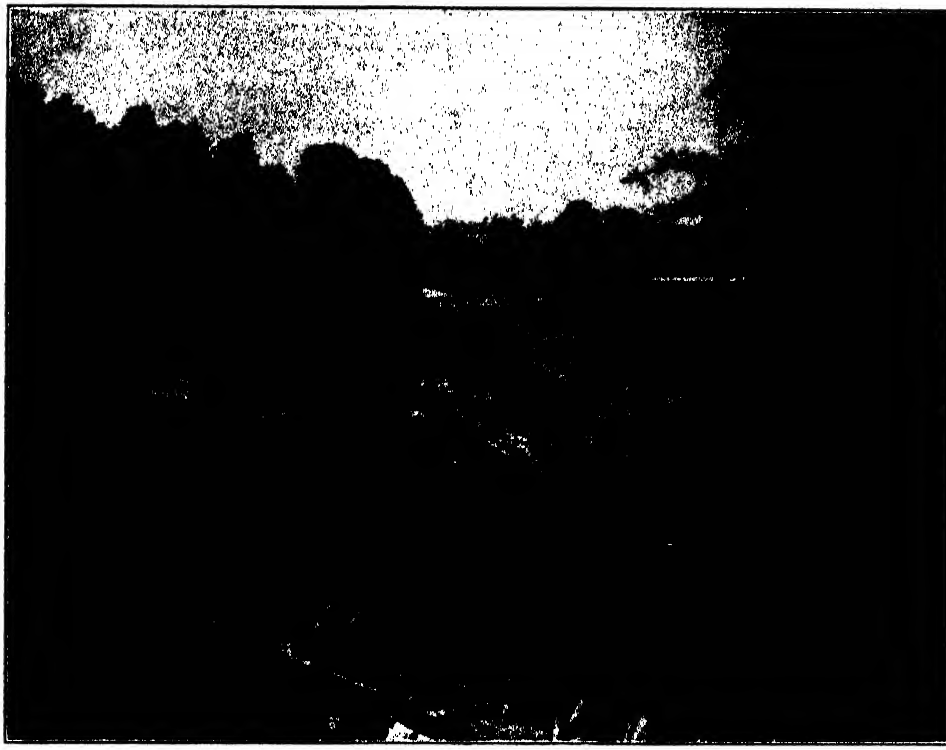
Field terraces (embankments ad-

justed to the contours) are being employed where applicable, and in some localities it is planned to scarify certain types of land (especially summer-fallowed ground) with a machine which scoops out 10,000 basin-like holes to the acre, each of which retains about five gallons of rain, causing it to sink into the ground where it falls (machines for this purpose are now being manufactured). Soil-conserving crop rotations are being practised, and cover crops and other control measures are being employed.

Every farm is surveyed in advance of actual work, by specialists of the local erosion staff. Soils, slopes and extent of erosion are plotted on accurate maps. With the aid of this, the farmer and erosion specialists go over the farmstead, study it in detail and on the ground plan a course of procedure by assigning each acre to a particular use, in accordance with its needs, adaptability and appropriate place in a carefully planned coordinated land-use program for that particular farm. The work is carried out on a strictly cooperative basis with the farmers. Generally the latter are enthusiastically supporting every phase of the program. On some of the projects more than 95 per cent. of the farmers are going along with the program of the erosion specialists, agreeing to far-reaching reorganization of their fields and farm procedures. For example, on numerous farms fences are being relocated so as to permit contour cultivation, terracing, strip-cropping, the inauguration of soil-building rotations and the planting of the more vulnerable slopes to grass, trees, etc. Such hearty cooperation, it is believed, insures the success of the program. By putting through these initial educational watershed projects in a highly impressive manner, it is felt that it will then be possible to extend the work to all areas through the activities of the Soil Erosion Service, the Extension Service, the colleges of agriculture and other organizations.

First Coordinated Erosion-Control Effort

Here is the first attempt in the history of the country to put through large-scale, comprehensive erosion and flood control projects, such as apply to complete watersheds from the very crest of the ridges down across the slopes to the banks of streams and thence to their mouths. These are not engineering projects or forestry projects or cropping projects or soils projects or extension projects, but a combination of all these, operated conjointly with such reorganization of farm procedure as the character of the land indicates as being necessary. This procedure is based on the best information in the possession of scientific agriculturists: agronomist, forester, range specialist, soil specialist, erosion specialist, agricultural engineer, economist, extension specialist, game specialist and geographer. It is the application of accumulated knowledge pertaining to the great multiplicity of variables affecting the 3-phase process of absorption, runoff and erosion, employed not as single uncoordinated implements of attack, but collectively, according to the needs and adaptability of the land, in a combination of integrated control measures, supplemented by new information accruing from the experience of combat. No such coordinated attack has ever before been made against the evil of erosion in this country. The plan was worked out largely on the basis of the writer's many years of experience in the study of soils and of land-use procedure in the United States, the West Indies and Central and South America; plus the experiences of other specialists familiar with the land and its utilization. Considering the physical, economic and social factors involved, it is believed there is no other possible practical method of ever mak-



RESERVOIR FILLED WITH EROSIONAL DEBRIS

TO THE TOP OF THE DAM (BUT NOT TO THE TOP OF THE FLASHBOARD EXPEDIENT ON TOP OF THE STONE MASONRY FOR MAKING SOME LAST, SHORT-PERIOD USE OF THE COSTLY STRUCTURE). PACOLET RIVER, 7 MILES NORTH OF SPARTANBURG, SOUTH CAROLINA.

ing any effective headway against this vicious problem (1). Even if the government owned the land, it would still have to be used over large areas in the production of crops and for grazing; and here again precisely the same physical problems would have to be met and conquered, an eventuality that unavoidably precedes all other consideration relating to correct land use.

Examples of Procedure

In the Wisconsin erosion project (covering Coon Valley, near La Crosse), for example, some of the steep timbered areas, now eroding because of excessive grazing, are being taken out of use and given complete protection in order to stop the excessive runoff of rainwater, which has been speeding down across the cultivated slopes, ripping them to pieces with gullies or planing off the more fertile topsoil. Grass is being restored to these protected forest areas, and where the trees are too thin other trees are being planted. Small plantings and seedings are being made that furnish feed and cover for quail and ruffed grouse. Eventually, with increased stocks of these fine game birds, saved from starvation during prolonged periods of snow, as was done last winter, sportsmen will come from Milwaukee, St. Paul, Chicago and other places to pay the farmer for the privilege of hunting in his timbered lands.

Below the forested land, the steep slopes now washing rapidly to a condi-

AIR PICTURE OF APPROXIMATELY 1,000 ACRES

SHOWING BOTH GULLY AND SHEET WASHING. ALL THE TIMBERED LAND WAS FORMERLY CULTIVATED AND THEN ABANDONED BECAUSE OF EROSION. THE TREES (DARK-COLORED AREAS) ARE SECOND-GROWTH PINE (OR THIRD- OR FOURTH-GROWTH PINE, DEPENDING ON HOW MANY TIMES THE LAND HAS BEEN CLEARED, CULTIVATED AND RE-ABANDONED). MOST OF THE LAND IS NOW ESSENTIALLY RUINED AND CAN BE PUT TO USEFUL PURPOSE ONLY THROUGH TREE AND GRASS PLANTING. SOUTH TYGER RIVER PROJECT OF SOIL EROSION SERVICE, NEAR SPARTANBURG, SOUTH CAROLINA.

tion of low productivity are being taken out of the clean-tilled crops and put into permanent pasture to furnish the grazing that formerly was provided by the timbered areas. The grazing capacity of the farms is not thus increased or materially decreased, but the crop area is cut down to some extent. Better protection of the cultivated land from erosion will largely make up for this reduction, by way of higher acreage yields.

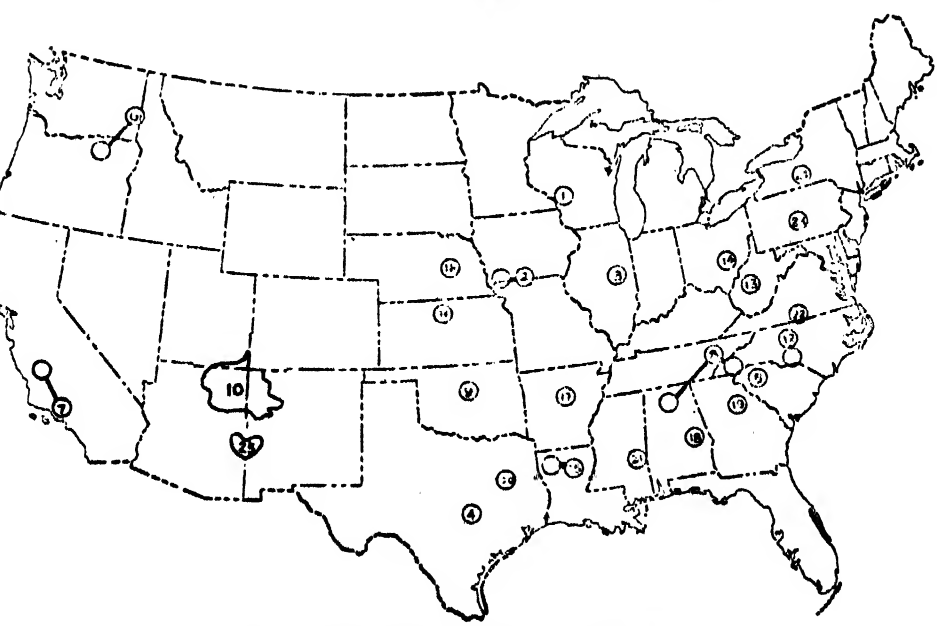
On the 150,000-acre watershed erosion project on Big Creek in north-central Missouri, extending into south-central Iowa, a report of progress submitted by the regional director of the soil erosion work, under date of June 23, 1934, includes the following highly pertinent statement with respect to accomplishment (work having begun on this area in the spring of 1934): "At this time we have 401 cooperative agreements signed up with the farmers of the Big Creek project, and over 63,000 acres of land under contract for a coordinated plan of erosion treatment. We have been successful in reducing the corn acreage over the next 5-year period by more than 37 per cent. on these farms. We have cut the acreage of land where corn follows corn for a second year (a very bad practise) more than 54 per cent. We have

very materially increased the acreage of pasture. We are planning an intensive program on pasture improvement, beginning this fall and continuing into next spring. While weather conditions have been quite unfavorable, it is felt that very good progress has been made to date.''

Thus, all indications point to successful achievement with these coordinated, educational programs of erosion control —which, it should be emphasized in conclusion, are of an experimental-demonstrational nature, and which, by reason of the necessary procedures involved with the accomplishment of a complete job, extend beyond the mere task of controlling erosion.

(1) It seems unfortunate that some single-ideaed (or perhaps under-experienced) specialists still insist that this powerful agency of accelerated erosion can be overcome through the use of single implements of attack. With the pages of experience laid open to eyes that see over millions of acres of land ruined for crop use and more millions impoverished, and with the wastage proceeding faster than ever, it is discouraging to hear these specialists contend, for example, that erosion can be controlled solely with terracing (embankments of earth adjusted to land contours). Most specialists understand clearly that terracing is a very useful method of assisting with erosion control (see ''A Proposed System of Erosion Control,'' *Agricultural Engineering*, V. 14, No. 6, June, 1933, pp. 150–151, by H. D. Sexton and E. G. Diseker). The system was devised about a hundred years ago in the southeastern United States and extensively employed, in several modifications, in that section, often with excellent results. In spite of the usefulness of the method, where properly applied, several million acres on which it was employed have, nevertheless, been abandoned because of continuing erosion. Some forty years ago Priestly Mangum developed on his farm near Wake Forest, North Carolina, a broad-base terrace which was a decided improvement over the older narrow type. This improved type, the Mangum terrace, has been extensively used since its development in various parts of the Southeast, and more recently it has come into quite extensive use in Texas, Arkansas and Oklahoma. Even the Mangum terrace, however, has not, where used alone, succeeded in controlling erosion, except on rather gently sloping land, although it has accomplished much good in slowing down the washing, especially where used on slopes not steeper generally than about 6 or 7 per cent.

Obviously, it is impossible completely to control erosion, a process that begins wherever rainwater contacts bare sloping ground, with



SOIL EROSION CONTROL PROJECTS

any implement which does not cover the entire surface. In other words, erosion goes on between the terraces, as well as on sloping soil exposed between any other installations of contour measures. Soil washes from below the upper terrace embankment to lodge against the next embankment below, where, according to common practise, it is plowed up and partly dumped over the embankment to renew its journey in the direction of tidewater. In this connection it might be added that we have recently been furnished with results of measurements of soil loss from terraced areas, misinterpreted as representing the entire acreage losses for the entire terraced field. Such reported losses were measured by collecting samples of the runoff, and its contained silt, at the ends of terrace embankments. The fallacy of presenting such results as measurements of acreage losses from entire fields is obvious. The simple facts involved are that the measurements represent only the soil that passes out of the field at the end of the terrace, leaving out of account entirely the much greater bulk of material washed from the upper slope of the inter-terrace area down to the lower slope, or into the terrace channel, where it is temporarily lodged and then passed on down the slope through the operations of "terrace maintenance"—as much lost, in so far as its place of origin is concerned, as if immediately dumped into the sea (since it is uneconomical under the American system of extensive agriculture to haul it back into the field). Of course, the temporary lodgement of productive soil material against any obstacle keeps it in the field, or on part of the field, for a while, and so gives some temporary benefit.

Still other features relating to this useful method of combatting erosion should be seriously considered before making indiscriminate use of it, otherwise more damage than good may result. The terraces must be accurately laid out and properly built, as a matter of course; but what is just as important is that they should be limited in their application, when used alone, to comparatively gently sloping areas, for the reason that on steep land larger embankments are required generally and the distance between them must be narrowed. Accordingly, so much of the fertile topsoil of the inter-terrace area goes into the building of the embankment that the land from which this surface material is removed is left poorer, where the soil depth is shallow, than it was, or is likely to be in some instances for generations to come. It must be remembered, too, that in building a terrace the slope is increased quite sharply along the lower side of the embankment, and accordingly susceptibility to erosion is increased at this critical point, unless stabilization is effected with some dense cover of vegetation, as grass.

But when we begin to support one measure with another, especially when we make use of nature's most powerful agency of controlling erosion—densely growing vegetation—as in the instance of stabilizing the vulnerable lower side of a terrace embankment with grass, we have, in that sensible acceptance of a supplemental agency, ceased to be advocates of a false practise—the practise of fighting erosion solely with a single implement, whether it be terracing, strip-cropping or what. It should be pointed out, of course, that, when the ground is completely covered with good stands of grass or trees or other dense types of vegetation, then with a single implement we may have complete or very nearly complete control of erosion (see charts, Trans. Am. Geophysical Union, Nat'l. Research Council, pt. 2, pp. 474–88, 1934, showing comparative soil losses from clean-tilled land and land covered with grass or trees). This paper, however, deals primarily with erosion on cultivated land, where the entire area can not be covered with such control measures.

PROLONGING THE LIFE SPAN

By Dr. C. M. McCAY and MARY F. CROWELL
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The preservation of life, the defending of the human body from decay, and of rendering it a fit tenement for the soul to inhabit, in that season in which she is most capable of exerting her noblest faculties, are grave and serious subjects with which no trivial matters ought to mingle.
—*Hermippus Redivivus.*

In this day when both children and animals are being fed to attain a maximum growth rate, it seems little short of heresy to present data in favor of the ancient theory that slow growth favors longevity. A hundred years ago when men first became conscious of the need for the accessory factors which we now term vitamins, the field of nutrition was broad. Students attempted to study the requirements of both adult and growing animals. To-day research has tended to narrow into a channel of primary interest in the young, growing animal. Interest is centered on the growth and apparent health of this animal. After it becomes an adult it is no longer an "apple of the eye" of the nutritionist, but primarily a carcass that provides dissecting material for the pathologist. The nutrition student is too busy pouring vitamins, minerals and proteins into the young and growing to be much concerned with the grown.

The philosophy which dominates the field of nutrition assumes that a young animal which grows rapidly is the ideal for maximum health both during the growing period and during adult life. This philosophy has developed under the influence of several stimulants. In the first place, a young animal such as the white rat, which is the central interest in most nutrition laboratories, grows to maturity in about three months. Studies of the growth of this animal provide opportunities for numerous discoveries in the course of a short-time period. Technical journals are cluttered to-day with thousands of reports concerning the growth of the white rat. But if one tries to discover the length of life of this widely used animal, he will not find five good reports in the entire literature.

A second stimulus to this interest in the growing animal and disregard of the adult is due to the public interest in the young and growing. The healthy adult is a matter of little interest, even to himself, and the sick one usually rates as a pest. This philosophy belongs properly to the butcher. Every producer of meat animals wants to rear them rapidly because it is economical. These animals are killed as soon as they mature. What agricultural expert can tell the effect of the feeding during the growth period upon the milk-producing capacity of a cow during her entire life? What chicken specialist can tell the effect of the rate of growth of the chicken upon the egg production of the laying hen? Who can tell you the effect of the rate of growth of a child upon its susceptibility to disease during adult life? Who can give assurance that the child that matures rapidly will not die after a short life span?

A third stimulus whose importance may be overlooked is that of commercial advertising. While preparing this note I selected at random one of the copies of the *Journal of the American Medical Association,* which is published weekly. More than a fifth of the advertising in this journal was devoted to fortified foods for children, chiefly for defenseless babies that are more or less easily coerced into engulfing various vitamin

concentrates. It must be possible to market such products. Who can estimate the effectiveness of such constant advertising in the *Journal* of the American physician in creating and moulding his philosophy and his recommendations in feeding children? Is it any wonder that the pediatrician has become an advocate of rapid growth? Even the manufacturer of scales does his part by buying space in this same professional journal in order that no one shall neglect to keep his child up to date in weight. Thus has been created an enthusiasm for growth and growth stimulants. And what profit in dollars can be made from any other philosophy?

Before becoming involved in experiments and data it may be well to refer briefly to three philosophers. In his treatise upon the generation of animals Aristotle states:

> The period of gestation is as a matter of fact determined generally in each animal in proportion to the length of its life. This we should expect, for it is reasonable that the development of the long lived animals should take a longer time.

If we turn to the Opus Majus of Roger Bacon (1214–1294) we read:

> Another example can be given in the field of medicine in regard to the prolongation of human life, for which the medical art has nothing to offer except the regimen of health. But a far longer extension of life is possible. At the beginning of the world there was a great prolongation of life, but now it has been shortened unduly.

Further in this same work we read:

> Therefore in regard to this we must strive, that the wonderful and ineffable utility and splendor of experimental science may appear and the pathway may be opened to the greatest secret of secrets, which Aristotle has hidden in his book on the Regimen of Life. For although the regimen of health should be observed in food and drink, in sleep and in wakefulness, in motion and in rest, in evacuation and retention, in the nature of the air and in the passions of the mind, so that these matters should be properly cared for from infancy, no one wishes to take thought in regard to them, not even physicians, since we see that scarcely one physician in a thousand will give this matter even slight attention. Very rarely does it happen that any one pays sufficient heed to the rules of health. No one does so in his youth, but sometimes one in three thousand thinks of these matters when he is old and approaching death, for at that time he fears for himself and thinks of his health. But he cannot then apply a remedy because of his weakened powers and senses and his lack of experience.

In another paragraph Roger Bacon continues:

> Since I have shown that the cause of a shortening of life of this kind is accidental, and therefore that a remedy is possible, I now return to this example which I have decided to give in the field of medicine, in which the power of medical art fails. But the experimental art supplies the defect of medicine in this particular. For the art of medicine can give only the proper rules of health for all ages. For although noted authors have spoken inadequately concerning the proper regimen of the aged, it has been possible, however, for medicine to give such a regimen. This regimen consists in the proper use of food and drink, of motion and rest, of sleep and wakefulness, of elimination and retention, of the air, and in the control of the passions of the mind. But if from birth a man followed a proper regimen to the end of his life he would reach the limit of life set by God and nature, in accordance with the possibility of a proper regimen. But since it is impossible for this regimen to be followed by any one, and since few, nay, scarcely any one at all, from youth pay any heed to this regimen, and very few old people observe it as it is possible, therefore the accidents of old age of necessity come before old age and senility, namely, in the period of the prime of life, which is the age of human beauty and strength. In these times this period of life does not continue beyond forty-five or fifty years.

This scientist and monk of the middle ages continues:

> Not only are remedies possible against the conditions of old age coming at the time of one's prime and before the time of old age, but also if the regimen of old age should be completed, the conditions of old age and senility can still be retarded, so that they do not arrive at their ordinary time, and when they do come

THESE TYPICAL RATS ARE BOTH 900 DAYS OLD

THE ONE ON THE LEFT GREW RAPIDLY AND "NORMALLY" TO MATURITY WHILE THE PHYSIOLOGICALLY YOUNG ANIMAL ON THE RIGHT WAS RETARDED IN GROWTH AND FORCED TO MATURE SLOWLY.

they can be mitigated and moderated, so that both by retarding and mitigating them life may be prolonged beyond the limit, which according to the full regimen of health depends on the six articles mentioned. And there is another farther limit, which has been set by God and nature, in accordance with the property of the remedies retarding the accidents of old age and senility and mitigating their evil. *The first limit can be passed but the second cannot be.*

As every one is well aware, this usefulness of the experimental method in attacking the problems of longevity remained unheeded, as it has to this hour. A few hundred years after these words of Roger Bacon we read the statements of Lord Francis Bacon (1561–1626):

We make the third part of medicine regard the prolongation of life; this is a new part, and deficient, though the most noble of all; for if it may be supplied, medicine will not then be wholly versed in sordid cures, nor physicians be honored only for necessity, but as dispensers of the greatest earthly happiness that could well be conferred on mortals for though the world be but as a wilderness to a Christian travelling through it to the promised land, yet it would be an instance of the divine favor, that our clothing, that is, our bodies, should be little worn while we sojourn here. And as this is a capital part of physic, and as we note it for deficient, we shall lay down some directions about it.

In the light of our experimental data which follow, six of these rules of Lord Bacon may prove interesting:

(1) The cure of diseases requires temporary medicines but longevity is to be procured by diets.

(2) It seems to be approved by experience that a spare and almost Pythagorean diet, such as is prescribed by the stricter orders of monastic life or the institutions of hermits, which regarded want and penury as their rule, produces longevity.

(3) Animals which come later to perfection (I am not speaking of growth in stature only but of the other steps to maturity as man puts out first his teeth, then his signs of puberty, then his beard, etc.) are longer lived for it indicates that the periods return in wider circles.

(4) To grow long and slowly is a sign of longevity and the taller the stature the better the sign. But on the other hand, rapid growth to a great stature is a bad sign but to a shorter stature less bad.

(5) I would have men duly to observe and distinguish that the same things which conduce to health do not always conduce to longevity.

(6) Again there are other things very beneficial in prolonging life yet that are not without danger to the health unless guarded against by proper means.

Finally before considering data it is worth noting some statements from a

more modern work, "La Philosophie et la Longevité," of Jean Finot. In 1906, just as the extensive modern interest in vitamins was taking form, Finot wrote:

> Here is a fact in another type of idea, which has cost the lives of millions of men. From many observations we have learned that the vitality of the world's animals is in direct relation to the duration of adolescence. The more the period of adolescence is extended, the more that of maturity is increased. All the education and instruction given to children is in violent contradiction to this law. All our efforts tend to the most rapid advancement toward physical and intellectual maturity.

As we enter the contemporary field of experimental science we need not be surprised that real data bearing upon the problems of longevity are almost as scarce as they were in the time of Aristotle or Roger Bacon.

In 1917 Osborne and Mendel[1] reported an experiment in which they attempted to prolong the lives of rats by retarding the growth. They found the reproductive activities of these rats extended to a greater age in the females, but unfortunately their rats died of disease before they determined the effect of retarded growth upon the life span. In 1917 Northrup[2] presented data with fruit-flies showing the entire life cycle was extended if you increased the larval period by inadequate feeding. The entomologist has long been aware that the total life cycle is prolonged by slowing down one of the stages of development.

In 1928 Raymond Pearl[3] in his book on "The Rate of Living" showed the significant negative correlation between the rate of growth and duration of life of cantaloup seedlings.

In our laboratory in 1927 an experiment was designed to study the relationship between the protein level in the diet of brook trout and the deficiency of an accessory factor we term "H" (to differentiate it from the vitamins required by higher animals). The diets for the series of groups of brook trout were all deficient in this essential vitamin, factor H. Therefore in the course of six months or less every trout was doomed to die. In addition to this vitamin deficiency, which was common in all diets, the amount of protein in the various diets was varied. One group received 10 per cent. protein, another 25 per cent., another 50 per cent. and a fourth 75 per cent. To secure growth, a diet for brook trout must contain about 14 per cent. protein. In this experiment all groups grew at about the same rate, except those upon the low level of protein. They failed to grow, but kept alive. However, the trout that grew died in about twelve weeks. Those that failed to grow upon this low protein level lived twice as long as those that grew. Thus it was postulated by us in 1928 that *something was consumed in growth that is essential for the maintenance of life.* At a later date this experiment was repeated and again it was found that trout that grew lived about half as long as those that were retarded in growth if both were kept upon a deficient diet.

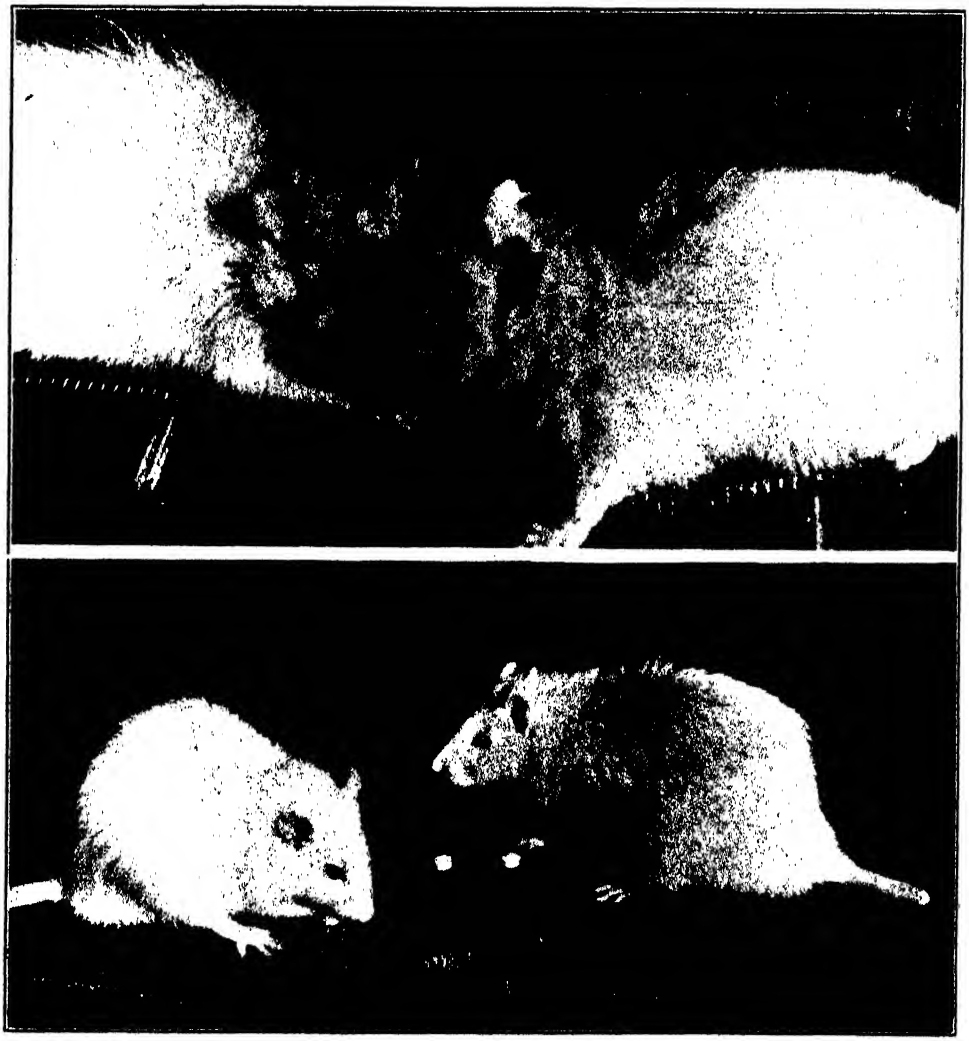
While considering these studies with fish it may be well to review briefly the difference between the growth rates of fish and those of higher, warm-blooded animals.[4] If a young elephant in a zoo gained a pound in a day no one would be excited, but if the mouse that steals the elephant's food were to gain a pound a day it would be news. Therefore in considering the growth rate of any animal it must always be considered in terms of the body weight of the individual. Thus it can be stated better that the mouse and the elephant gain a given per cent. of their respective body weights

[1] T. B. Osborne, L. B. Mendel and E. L. Ferry, *Science*, 45: 294, 1917.

[2] J. Northrup, *Jour. Biol. Chem.*, 32: 123, 1917.

[3] R. Pearl, "The Rate of Living," Chap. 7, 1928.

[4] C. M. McCay, *Science*, 77: 411, 1933.



FEMALE RATS AT THE AGE OF TWO YEARS AND EIGHT MONTHS

Those above belonged to Group 1 which grew to maturity rapidly. The physiologically young ones below are the same age but they were retarded in growth and matured late.

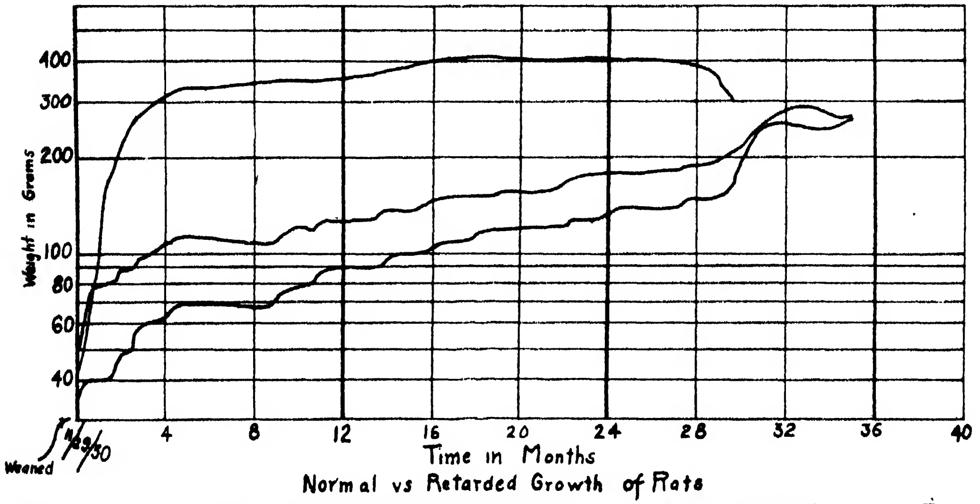


CHART. THE TOP CURVE SHOWS THE GROWTH OF A "NORMAL" ANIMAL FROM GROUP 1. THE TWO LOWER CURVES ARE TYPICAL FOR ANIMALS RETARDED IN GROWTH.

in a unit of time such as a day or month. In practise we determine such relationships automatically by plotting growth curves upon semi-logarithmic graph paper. Most higher animals from their early life in the uterus grow at a constantly decreasing rate. The baby tends to grow more rapidly than the boy of sixteen. This is not so with fish such as brook trout. In a given year during the growing season they maintain a constant growth rate. In other words, in each month the brook trout increases its weight by a constant per cent. of the body weight at the beginning of the month. If the entire life span of a brook trout is considered, however, it is found that the growth curve remains logarithmic during successive years. This curve is much steeper during the "fry" stage and during that of embryonic growth than it is during the second and third years of life. Thus the trout really decreases its growth rate as it ages and does not afford an exception to the findings of Minot that warm-blooded animals decrease their growth rates as they become older. Not only is this growth rate logarithmic but it is much slower than that for a pig or a chicken. No one has published growth curves of warm-water fish for comparison, however. Not much is known about the life span of fish, but it is well recognized that they are long lived. There is a record of a carp that lived 367 years, of a pike that lived 267 years. The authenticity of these records may be questioned, but it can be accepted that fish have long life spans.

As the discovery that trout live longer when they fail to grow is reviewed, the old law which Buffon (1707–1788) seems to have taken from Aristotle is worth recalling. Buffon claimed that the time required for an animal to grow to maturity could be multiplied by 6 or 7, and the resulting value would equal the life span. This law was discussed at intervals in the course of the eighteenth and nineteenth centuries. To-day it seems pretty well forgotten by the biologists. This law is interesting because it states that the life span is directly proportional to the growing period of a young animal. This law was devised from a consideration of the growth rates of various species such as

man, camel, horse, cow and dog. It was not based upon data concerning individuals within a given species. This law is interesting because it suggests a possible method of extending the life span of an individual. It also makes one aware of the many animals of widely different life spans that are available for experiments. Thus man is fortunate in having a much greater span of life than mice, rats, guinea pigs, chickens, rabbits, cockroaches and dogs. Within our reach is the possibility of determining the factors that set this limit to the life span or possibly to discover that the fixed life span is fictitious.

In order to test the assumption that an individual within a species that grows to maturity slowly will have a greater life span than one that grows rapidly, an experiment with white rats was designed. This species was selected because (1) its nutritional requirements are better defined than those of any other species. This has been the chief animal used in the laboratories for the past twenty years. (2) The white rat's span of life is about two years, normally. Therefore, an experiment would not need to extend over a period of more than five years. (3) The white rat is small enough so that large groups can be employed. Thus we can compensate for individuals that develop specific diseases that are not related to the experiment. (4) Numerous earlier studies had shown the white rat can be retarded in growth and still attain maturity. No marked stunting effect results from retarding the growth at least as far as any one has extended such retardation. (5) The white rat is similar to man in its nutrition and in the life spans of the opposite sexes. The female rat lives longer than the male. This is also true for the human species.

In planning the diet for this experiment it was desired to satisfy the nutritional requirements of the body in every respect, except that the body would have insufficient calories to permit growth when the food intake was restricted. We designed a diet that was adequate in vitamins, protein, inorganic salts and fats, even when the animal was restricted to a low level of intake each day. Thus for long periods the animals whose growth was retarded could be prevented from growing. At the same time the food ingested each day provided every recognized constituent to insure the health of the animal but not enough calories to permit growth. In such a case the real cause of the retardation of growth is probably due to the use of the protein for energy, since insufficient calories are allowed. Thus in final analysis the retardation may be due to protein in spite of a high level in the diet fed. This is analogous to an automobile in which the engine contains ample oil, the differential is well greased, the battery gives a good spark but only enough gas flows into the carburetor to permit the car to run 20 miles an hour. To make it run faster we feed the engine more calories. Likewise with the rat, the diet was adequate in every known respect. It was designed so that all that was needed to make the rat grow or to increase from its uniform rate was to feed it more calories. Sugar provides calories for the rat just as gasoline does for the automobile. No one expects "longevity" in an automobile without oil, grease and a few repair parts in addition to fuel. Likewise in the body of an animal we must have protein, inorganic material, vitamins and some fat. With these needs satisfied it was possible to control the rate of growth of the animals by calories alone.

In planning an experiment in which the growth of a young animal is retarded, it seems desirable to start as early as possible. In the case of the nursing young it is difficult to decrease the growth rate very much and still

TABLE I

LIFE SPANS OF RATS THAT MATURE SLOWLY COMPARED WITH THOSE MATURING RAPIDLY

Diet	Mean Life Span (Days) ♂	Mean Life Span (Days) ♀	Median Life Span (Days) ♂	Median Life Span (Days) ♀
I—Adequate calories (rapid growth)	509	801	522	820
II—Deficient calories (slow growth)*	(792)	(755)	797	904
III—Deficient calories (slow growth)*	(883)	(824)	919	894
Stock Diet (75) (rapid growth)†	503 ± 12		*Note:* Campbell discards early deaths while our data include them.	
Campbell‡ (A) (rapid growth)	576 ± 10	604		
Campbell‡ (B) (rapid growth)	635 ± 12.9	664		

* Values in parenthesis are still increasing, since the animals are alive.

† From unpublished data obtained from our rat colony five years ago.

‡ H. Louise Campbell, Thesis, Columbia University (1929).

keep the young alive and healthy. Furthermore, there is a transition period in which the animal is weaned and changed from milk to solid food. Retarding the growth during this period is also somewhat dangerous, since most species are very sensitive to changes during this time. In view of the difficulties in animal life immediately after weaning this experiment with rats was planned so that three groups were employed.

At the time of weaning 106 rats were divided into three groups, one containing 34 individuals and the other two 36 each. The members of one group were allowed to grow normally for two weeks they matured rapidly. The members of the second group were forced to grow very slowly by limiting their daily allowance of food from the time of weaning. The third group of rats was allowed to grow normally for two weeks after weaning. They were then restricted in their food allowance and forced to mature slowly. This restriction, providing all the necessary elements as we have stated, limited only the calories.

In the accompanying growth curves, the chart, we have selected curves for typical rats from each of the groups, and thus the course of growth is shown graphically. In rearing the retarded growth groups the practise has been followed of keeping them at a stationary weight for one to four months. A weight increase of about ten grams was then obtained by increasing the allowance of food. Part of these increases were made by feeding sugar only in addition to the regular allowance of food. At other times the step upward in the growth was induced by such rich sources of vitamins as beef liver. In each case the controls were also allowed the same additional and special foodstuffs, as the retarded growth groups during the same period of time.

In the accompanying chart the slow climb to maturity of the lucky rats or victims (as your philosophy dictates) can be seen. After more than 28 months all were allowed to mature. For the remainder of their lives they were allowed all the food they desired. Thirteen of these original rats were still alive after 1,200 days. All these were rats whose growth was retarded. This represents 18 per cent. of those from retarded growth groups and none of the rapidly maturing.

TABLE II

NUMBER OF EACH SEX OF RATS ALIVE AT THE BEGINNING AND AFTER 1,200 DAYS, SHOWING THE INCREASED LIFE SPAN AFTER RETARDED GROWTH

Diet	No. animals start			No. animals alive at 1,200 days		
	♂	♀	Total	♂	♀	Total
I—Adequate calories (rapid growth)	14	22	36	0	0	0
II—Deficient calories (slow growth)	13	23	36	3	5	8
III—Deficient calories (slow growth)	15	19	34	2	3	5
Total alive			106			13

In Table I is a summary of the mean and median life spans which was made at 1,191 days. From groups I, II and III the only fixed value at 1,191 days was that for animals of diet I. Late in the first year of this experiment some of the females of the retarded growth groups were lost during the hot summer of 1931. This tends to distort the data for the mean life span of the females. For this reason the data for the median, which is a truer picture in this case, are included.

These data as well as those of Dr. Campbell of Columbia, which we have inserted for comparison, show that the life span of the female rat which matures rapidly is longer than that of the male. It is worth noting that the mean life span of the female rat in our experiments, even with rapid growth, was about a fifth longer than that found at Columbia. One can think of several explanations for this difference, such as diet or heredity. Another difference is that Dr. Campbell's rats were bred and bore young regularly, while those in our experiments were not allowed to reproduce. In this table are also inserted the results of an earlier experiment in which 75 male rats were kept in our colony until the end of their lives. Their mean life span was 503 days, while in the present case the value was 509 days. In these cases the diets and the years in which the experiments were run were quite different, but the growth rates and the life spans were similar. This affords additional evidence that the rate of growth and the life span are related if the diet is complete qualitatively.

The data are clear in regard to the male rat. They are less clear in regard to the female, since there are animals alive in each group except one. Furthermore, this table was made at a time well outside the period of the normal life span of our male rats but just outside the span for the female animals. Since even female rats that matured rapidly lived about a fifth longer than those of Miss Campbell, there is the possibility that growth of young within the uterus may remove some essential from the body of the mother and thus shorten her life span.

In Table II is a summary of the number of each sex at the beginning and at the end of 1,200 days, slightly more than three years. At the present time this experiment has been running 1,200 days and there are 13 animals alive. Since the average male rat lives from 500 to 600 days and the average man lives from 50 to 60 years, ten days in the life of a male rat is equivalent roughly to a year in that of a man.

Most of the rats that are alive now are more or less blind and some have been so for about half of the period. Thus it

seems that the eye fails before other parts of the body. These old animals, like old men, seem to be susceptible to lung infections and these seem to be the immediate cause of some deaths. The hair of the animals retarded in growth remained fine and silky for many months after that of the rapidly growing animals had become coarse. In studies with animals it is customary to observe the hair, since its condition frequently reveals changes that are taking place within the animal body.

In summarizing, these data indicate:

(1) That the life span of the rat is extended if the growth of the animal is retarded by inadequate calories and if an adequate intake of other essential nutrients is insured.

(2) That the potential life span of an animal species is unknown and greater than we have believed.

(3) That the difference in growth rates of the opposite sexes within a species may account for the differences in life span.

(4) That the problems of longevity can be attacked profitably to-day by means available in most nutrition laboratories.

Finally, in order that we may not become over-enthusiastic concerning the worth of longevity studies, it may be worth recalling the well-known lines of Lucretius with which he closes Book III of the "Nature of Things."

> Verily, a sure end of life is ordained for mortals, nor can we avoid death, but we must meet it. Moreover, we spend our time amid the same things, nor by length of life is any new pleasure hammered out. But so long as we have not what we crave, it seems to surpass all else; afterward, when that is ours, we crave something else, and the same thirst for life besets us ever, openmouthed. It is uncertain too what fortune, time to come, may carry to us, or what chance may bring us or what issue is at hand. Nor in truth by prolonging life do we take away a jot from the time of death, nor can we subtract anything whereby we may be perchance less long dead. Therefore you may live on to close as many generations as you will: yet no whit the less that everlasting death will await you, nor will he for a less long time be no more, who has made an end of life with today's light.

THE NEW POINT OF VIEW IN CHEMISTRY

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MAN'S interest in the physical world stretches from the farthest nebula to the nucleus of the atom. It is convenient to think of the world as being divided into parts on the basis of the measuring scale required in discussing it. Thus for the nebulae we think in terms of billions of light years. When we remember that light travels to the earth from the sun in about eight minutes we get some idea of how far it would travel in a year—the light year. Billions of light years is indeed a grand scale. The nebulae form an intensely interesting world, about which, however, relatively little is known. Much closer to us is the celestial world known to the ancients. The convenient scale for the planetary system is the actual distance in miles, and even for the stars we seldom require a scale larger than thousands of light years. This is the part of the world in which the laws of attraction and the mechanics which govern these bodies have been known for nearly three centuries. Indeed, if we will, we may know the time of an eclipse to the fraction of a second.

We next consider the world of everyday experience. In it we find the problems which send us searching into the world of x-ray dimensions, where lie the hidden causes of the properties of matter. To understand chemistry we must in fact master the forces which act between atoms when they are a hundred millionth of an inch apart. Here the last few years have brought revolutionary changes.

The analogous laws which began an epoch for celestial mechanics about three centuries ago have just been discovered in this fascinating chemical world. We now know that the forces between atoms arise entirely from the charges carried by the nuclei and electrons. This parallels the law of gravitational attraction for celestial bodies. Paralleling the Newtonian laws of motion we have the no less precise quantum mechanical laws of motion, together with the Pauli principle.

We pause to mention the last and smallest in these realms of human interest, the subatomic. Here the measuring rod is a million-millionth of an inch and the forces are gigantic. Here also the correct mechanics remains to be discovered and even the nature of the forces are shrouded in mystery. We may be sure, however, that this too is a mystery which human ingenuity will unveil, only to uncover newer mysteries beyond.

We now inquire what is the nature of this mechanics, which is transforming chemistry from a world in which every property of matter was of necessity empirical to one in which any property can be calculated—to be sure, at the price of enormous labor—but nevertheless it can be calculated. Since all the forces between the atoms arise from the fact that they are electrical charges, it is not surprising that when we can specify accurately the average relative position of these charges we can immediately calculate all their properties. The eigenfunction is the name given to the quantity whose square describes in detail the haunts of these particles, and the Pauli principle simply says that no two of these particles can simultaneously occupy the same haunts. This seems to be simply a highly sensible bit of atomic regulation to prevent overcrowding. Now the other important principle in quantum mechanics tells us how, by a slight but absolutely definite change, we obtain an operator from the Newtonian expression for a property which acts

upon an eigenfunction to yield the corresponding value of this property in our new mechanics.

This broad outline has been given simply to emphasize the fact that we now have this new mechanics which is a perfectly definite concrete system which all of us may, and those of us who are chemists must, if possible, learn to apply.

One naturally wonders, first, if there really is a correspondence with reality of this set of abstract operations and, even if there is, how the correspondence arose. In answering this, we should remind ourselves that the process of thought is itself experimental. When we start thinking about something strangely new, many of our ventures lead nowhere, but, if we try often enough, we finally build a logical system which is a faithful mirror of reality. If this system is well built, continuing the structure reveals a part of the physical world beyond previous experience. It is not strange, then, but certain that, if brilliant men think long enough about a rich world of experience, such as spectroscopy was during the first quarter of this century, a great logical method will arise which may be used to penetrate deeper into our unknown world.

What are some of the questions which we are called upon to unravel? The first is the great realm in which nothing changes with time. A typical question follows. Suppose there is oxygen in a vessel at a certain temperature and pressure, what fraction of the oxygen will be present as atoms and what part will be present in the form of oxygen molecules, each containing two atoms. This is a question extremely difficult to answer experimentally, to temperatures higher than about 1000° C., even approximately. With the help of spectroscopy and quantum mechanics precise values have been given up to about 6000° with comparative ease. This is a phase of the great chemical revolution of which very many equally striking examples could be cited, but instead we turn to an even more interesting question. How fast do chemical changes take place in the world? Life itself is but one phase of this fascinating question.

For molecules to combine to form new ones they must collide with catastrophic violence. The atoms in the two colliding molecules must approach so closely that they no longer know whether they are bound to the new or the old atoms. For convenience, this is known as the activated state. If these violent encounters occur once in every million million collisions, the reaction goes moderately fast. If they go once in every thousand million collisions an experimental chemist will be unable to distinguish between this and reaction on every collision. He will simply say in either case that the reaction goes immeasurably fast. By cooling his vessel he slows down all the molecules and can so cut down his rate to something measurable. Thus, simply by observing how a chemical reaction changes with temperature, he can tell you how violent a collision must be in a particular case to cause reaction; but, until the last three or four years, he could not even guess how violent a new type of collision must be to bring about a reaction. This the quantum mechanics has completely changed. He can now calculate, as accurately as he pleases, how energetic a collision must be to cause chemical change and, therefore, at what temperature it has a measurable rate. Moreover, approximate calculations, which are simply made, frequently tell him which of two reactions will go the faster. This is a type of question which to answer experimentally frequently requires a great amount of time and great expenditures of money.

For the exact calculations one needs no other data than the laws of quantum mechanics and the fact that one is dealing with a certain set of charged particles, and all the physical and chemical properties would emerge as a matter of

course. For the approximate calculations one derives an algebra which expresses the energy of complicated systems of atoms and molecules in terms of the energy which would bind the individual pairs if, in each case, the other atoms were not present. The binding energy for any pair is generally obtainable by well-known means from the lines of the spectra of the pair.

What particular types of questions may be answered in this way? Frequently it is observed that molecules which react together slowly, if at all, when left to themselves become enormously reactive in the presence of a certain solid surface, while others are speeded up by means of minute traces of certain enzymes also acting as catalysts. We first inquire why a particular substance is catalytically active, and secondly, what are the properties which a new substance must fulfil to serve equally well. Such calculations show that only atoms on a catalyst with the spacing proper for the particular reacting molecules will have the maximum effectiveness. It also gives just what this spacing should be in particular cases. Further, we find that the particular effectiveness of metals arises from the additive nature of the metal bonds. This is the very property which makes them form the characteristic metallic structure in which every atom is strongly bound to many neighbors. One need only remember that the possibility of the synthesis of ammonia by these same catalytic methods made possible the late war to appreciate in what a fundamental way such processes affect us all.

These same methods serve to calculate simply and easily how closely two molecules will approach in an ordinary collision, thus defining what has always been thought of as the size of the molecules. Another interesting phenomenon long known to chemists arises when an atom in a molecule is replaced by a large group which gets in the way of an oncoming molecule during a collision that would otherwise result in reaction. This makes it necessary for the reaction to be more violent by an amount which agrees with the calculated values in an interesting way. There are of course many such examples that could be cited, but we turn now to the interesting field of isotopes.

Soddy originally defined two isotopes as two molecules having identical chemical properties but different atomic weights. Perhaps heavy hydrogen or deuterium, discovered by Urey, Brickwedde and Murphy, has shown its iconoclasm in no more striking manner than in the absolute scorn it shows for this interesting definition. In fact, Professor Soddy has even suggested that rather than amend the definition it seemed wiser to discard the idea that deuterium is an isotope of hydrogen and instead regard it as a new element. Such a proposal of course does not remove the difficulty, since in fact any two isotopes differ in chemical properties by an amount roughly proportional to their masses, so that for the heavier atoms the results only become smaller but never disappear.

The whole theory of the separation of isotopes and the difference in chemical reactivity arise from a difference in the bond strengths for the two isotopes. This in turn arises from the so-called "different zero point energies," which we may explain in the following way. Because the deuterium and hydrogen atoms each have a single negatively charged electron with a nucleus carrying a single positive charge a pair of atoms of either kind exert almost exactly the same forces on each other at the same distances. However, the quantum mechanics tells us that such a pair of atoms has the peculiar property of retaining a definite amount of vibrational energy, even at the absolute zero of temperature. This amount being proportional to the frequency of vibration and with the

same forces pulling on them, it is clear that the lighter ones will vibrate more rapidly. The result of this is of course that because the light hydrogen has the most energy to start with less will be required to break it up into atoms or to shatter it enough to permit it to react with any other molecule.

Such considerations show that if you had a solution containing one half ordinary water and the other half heavy water then, in the gas phase above the molecules, there will be very few ions of either kind, but there will be twelve times as many hydrogen as deuterium ions. Since the lighter hydrogen ions also move 40 per cent. faster than the deuterium ions, you would find, if there were a tiny hole in your apparatus which would only allow ions to pass, that 18 times as many light as heavy hydrogen ions would emerge. This of course would give a very excellent separation of the two kinds of water but unfortunately at a very slow rate. However, this slowness is remedied by passing an electric current through the water and so forcing the ions to leave the solution and allowing them then to combine to give hydrogen and deuterium on the metal electrodes. If the electrodes are made of platinum the separation factor, instead of being 18, as in the ideal case, is only 8. If the electrodes are made of mercury this factor is 2.8. Iron and nickel give values of 7 and 5.5, respectively. The differences from the ideal separation factor, although fairly well understood, are of no particular interest to us now. The interesting point is that you get separation of light and heavy water no matter what metal you use for your electrode or what substance you dissolve in your water, and the only reason some one did not find it a hundred years ago is because they did not try. They did not try earlier because they did not understand spectroscopy sufficiently well to identify the spectral lines; but, most of all, they did not know the quantum mechanics which would allow them to know exactly the position of the old lines of hydrogen nor the possible new faint ones for deuterium.

From what has been said it must be clear that, in general, hydrogen will react from 3 to 18 times faster than deuterium if the process involves breaking a hydrogen or deuterium bond. Deuterium may react slightly faster in the rare cases in which the reactants are the free atoms.

What value will deuterium have in the study of reactions? If, in a reaction, the slow process involves breaking a hydrogen bond, then when we replace a hydrogen by deuterium the reaction will be found to go much more slowly. Conversely, if we find a deuterium compound reacts more slowly than the corresponding hydrogen compound the rate-determining step in the reaction must involve the breaking of a hydrogen or deuterium bond.

The field of biochemical reactions is of course a complicated one, but we are at least safe in saying that all the considerations mentioned above should be valid for such cases also. Often of secondary importance are the different physical properties of deuterium water, such as lower dielectric constant and lower solubility of dissolved compounds, greater density, boiling point, freezing point, and so on, although they are by no means negligible. There are of course a very great number of interesting examples illustrating these effects already known. We shall mention here but two. Various people, including Lewis, have shown that compounds of hydrogen not ordinarily thought of as acids still have the property of having their hydrogen atoms replaced by deuterium when dissolved in heavy water. This of course should remind us that even though compounds do not have hydrogen atoms so loosely bound that they act like acids they may still be loose enough that they can react once in every thousand million

collisions and so have the appearance of going instantaneously.

Another startling result of Taylor and Pace is that both hydrogen and deuterium are taken up by solid chromium oxide equally rapidly. The specialists in the field of catalysis, particularly Taylor, have always assumed that the slow process in the activation of the hydrogen at surfaces involved the breaking of hydrogen or deuterium bonds, but this seems to indicate that the slow process involves some preliminary rearrangement in the chromium oxide itself, which is a rather startling result. More cases must be studied before we can feel certain of such an interpretation. This should, however, give one a feeling for the kind of fundamentally interesting problems which this new isotope prepares us to attack.

It is perhaps of some interest to indicate the expense attached to the manufacture of heavy water. At Princeton at the present time there is produced 3 cc a day at a cost of about $5 to $8 a cc to be compared with earlier estimated costs of a number of people of $80 and more per cc. The method of procedure is very simple and has in fact been described elsewhere.

Perhaps the most striking of the very recent work on isotopes is the discovery of hydrogen of mass three. Rutherford and his coworkers, bombarding NH_4Cl with deuterium, discovered that atoms of tritium, hydrogen of mass three, were formed. Gould and Bleakney at Princeton, using some of the 98 per cent. heavy water in a mass spectrograph, found that tritium is not present in ordinary water in quantities as large as one part in a hundred million. In the meantime, Bleakney and his coworkers developed a much more sensitive mass spectrograph and found that tritium does exist in ordinary water to the extent of two parts in a billion. Curiously enough, this is just barely outside the range of the earlier instrument used.

Quite recently, Professor Harnwell and coworkers at Princeton shot deuterium molecule ions at high velocities into other deuterium molecules and increased the amount of tritium by several fold.

It is easy to summarize the general properties of this new kind of very heavy water. In the first place, it would cost a million dollars a cc to prepare it if one used the same methods applied successfully to deuterium. To obtain one cc of this water one would have to electrolyze away the water in a pool a foot deep and 200 feet square. Tritium heavy water is 20 per cent. heavier than ordinary water, as compared with 10 per cent. for D_2O. The chemical reactions of tritium will be still more sluggish than those of deuterium. Under circumstances in which the latter reacts a fifth as fast as ordinary water the former will react a tenth as fast. There will be in fact little or no difficulty in predicting all the properties of tritium from the quantum theory and from a knowledge of deuterium. The prediction depends principally upon the zero point energies involved. Interestingly enough Polanyi and Eyring, using quantum mechanics to predict rates of chemical reactions, outlined the effects of zero point energy on reaction rates some time before the heavy isotopes were discovered in whose reactions zero point energy plays such an important rôle.

It has been my purpose to point out that the same rapid developments which followed the discovery of the laws of force and the mechanics of heavenly bodies almost three centuries ago are now beginning in chemistry and that we must expect a large part of chemistry to become rapidly transformed into a much more exact science. Individuals or universities who do not take account of the trends of the times and who fail to direct their efforts to meeting such changes are doomed to fall far short of their utmost possibilities.

MATHEMATICS—THE SUBTLE FINE ART

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I. Introduction

Mathematicians are often confronted with the question: "What is mathematics?" And a second follows in its train: "Why should mathematics be of interest to any but the few." Many definitions of mathematics have been given, but upon examination they have all turned out to be inadequate. A good many thinkers have given answers to the second question, but they have never been very convincing. It has been urged that mathematics is useful. So it is, and to many its sole reason for being is the same as that of the kitchen scullion. Some one must do the drudgery. It has been urged that mathematics is the most powerful aid to logical or correct thinking. And it is true that mathematics seems at least to be correct. And mathematics never loses its creations. One can take considerable pleasure in the fact that one of my students expressed himself thus: "I am heartily thankful there is one subject in my curriculum that remains the same to-day as yesterday." When one thinks about it he sees that in all the range of human thought, but one subject has steadily added to its riches, and never has thrown away anything—mathematics. Science denies this decade what it taught last decade. History is questioned on every side. The sciences of humanity are ever remade. With the exception of mathematics all knowledge is subject to revision. This is an excellent reason for becoming acquainted with it, but it is not a necessary reason. For we meet a new question: Is mathematics knowledge, and if so, knowledge of what? This reduces the second question to the first, and we must consider it before we can consider the other. What is mathematics?

In order to arrive at an answer we must go back, as Descartes did, to the human consciousness itself. What do we find in the conscious life of man as the dominant essences of that life? One is the ability to hoard the conscious life, to capture some of the wild birds that flit past our present. Another is the ability to wave a magic wand like Prospero and bring into being birds and butterflies, Ariel and all the trains of fairies, castles and storied towers, music and poetry. Man is a dreamer, but some of his dreams he can capture and keep.

These two characters have been evident at all times in the long stretch of the human race from the dawn of history to the present. Man has never accepted the world around him as do the animals. He has always undertaken to change it and make it into something different. He makes water run uphill; he piles up stone or steel even to the clouds; he tames the wild beast and puts him to work; he talks 'round the world; he protects himself so that he lives in the tropics or at the poles. Sometimes he is whirled about in the winds of nature, but he does not accept this fate. He remembers what he has done in the past and wherein he failed, and on the basis of these memories, which he calls knowledge, he conceives visions of what he can do in the future. He is constantly endeavoring to let loose an innate power, a desire for activity. It is not necessarily practical work he is doing, for just as often it is the exercise of the play desires he possesses. He often undertakes projects that have no particularly practical end. The dance for the green corn is to cause good crops, but it is also the outlet of spiritual

power. What practical end does "The Tempest" serve? The modern slender spire that rises up in the heart of a swarming city is practical, perhaps, but it is far more the satisfying success of an artist to realize a dream. Man knows that he is not a mere spectator in the universe of phenomena, seeing things only by "flashes of lightning, all the rest darkness." Neither is he a walking doll, that says "mamma," then goes to the ashbarrel when broken. He is an adventurer, often undertaking the impossible, and making it possible. He is the living volcano of flame and dust which must release its power.

But his life is not simply the exhibition of activity. There is inside him, not always consciously, a longing which haunts him, a longing for an invisible, intangible, inaudible reality called beauty. This he finds is just as insistent as the desire for comfort. He must build a habitation for shelter, but he does more than this, for he builds it in such a way as to satisfy this desire for an elusive thing which later he calls beauty. In time this indeed comes to be more important than anything else, for he sees that this reality indeed is himself. It is a glorified expression of that which he sees himself potentially to be. Whatever means he may make use of will be as inadequate as are paper and ink to carry the impassioned lover's rhapsody. When the first primitive tribe with sweating labor managed to stand on end a huge monolith, their expression of the majesty and power of their first vague intuition of the Unknown, their own dim consciousness of capabilities, of powers to be attained only in the tedious march of centuries, reaching up higher than they, solid and undisturbed by rain or frost, was there nothing real and permanent for which this clumsy symbol stood? Even the archeologists and ethnologists who see in it nothing but a phallic symbol have to admit that the insurgency of life and the urge to creation are worth a symbol which shows them as eternal realities.

The twofold character of the psyche is easily evident with only a small amount of reflection and very little insight. There is the ability to crystallize the evanescent and flowing waves of events into definite and stable forms, and this is called knowledge. Then there is the constant urge to create new elements, more spontaneity, unguessed and undreamed forms of the inner life, and this is called art. So fleeting is the configuration of the psyche that the fixed and stable elements are ascribed not to it but to an objective world which is assumed to be independent of the psyche. Knowledge is assumed to be an understanding of an extraneous entity. Art is assumed to be mere play of the spirit, fleeting emotion, of only passing interest. Both assumptions are incorrect, since knowledge is the more or less temporary system of invariants the psyche plays with, while art is the emergence of the new life-forms of the psyche itself. Those creations of the psyche which it retains for awhile constitute knowledge, and the creating of a new form is art. It is easy to restate knowledge, since its forms are for awhile permanent, but to state art one must accompany the wild duck in its flight, must freeze the rainbow the sun produces against the shower of events. This means of course that knowledge and art are human, even though they plumb the absolute. What sort of psychical material a Martian cherishes as knowledge we can not know. What sort of art he creates we can not know either.

The stable routes from one item of knowledge to another we call logic. They seem to us to be necessary, but merely because we have made them habitual in going from one judgment to another. To find other routes would be an act of creation, which would be art,

not logic, and this process of making new logic is actually going on. Stable modes of art would be impossible, since creation implies the unexpected, the versatile, the ever-new. This does not mean that in the creative process there is not a permanent reality. Reality does not mean fixity, crystalline structure. Any organism that maintains its individuality as an organism, even though subject to a steady flux of material, even though every atom, material or mental, is changing momentarily into a new atom, is still a reality. The human body is a reality, the immaterial sieve through which chemicals flow. The reality of art has this nature. An easy example is dual symmetry, the complementary phases together constituting the unitary symmetry. This may be in positive and negative number, geometric reflection in a plane mirror, in sine and cosine, in wave and particle, in the façade of a temple, in the right and left of the human form, in the purple and yellow of the sunset, in the assonance and dissonance in music, in the earthly and the heavenly love, in male and female, in good and evil—what matter the medium in which the dual symmetry express itself? The reality is that which generates the symmetry, the forms are adventitious. The stable idea of symmetry is knowledge, the actualizing of symmetry in some form is art. Indeed, knowledge and art are phases of a dual symmetry in the psyche itself, though there may also be found trinities, quaternities and an unlimited variety of other forms. The struggle of the poise of the spirit with its medium of expression is often intense: "White, white blossom, fall of the shattered cups day on day."[1] To many of the realities of art there do not correspond ideas; they are not expressible in the abstractions and static forms of language. The nearest approach in language is in creative, metaphorical, suggestive poetry. Hence stating an example in words is very inadequate, it is at best only a sort of ticket for reality itself. "Art is the very flowering, the tangible flowering, of the creative soul come to ecstasy."[2]

There is a constant interplay of the two characters of the psyche. It is the creative character which furnishes knowledge its hypotheses, the most steady source of advance in science. It is the crystallizing character which furnishes art its types of expression, the most steady source of production of art works. Research goes on all the time both ways. On the knowledge side it usually consists in an increase in dispersive power so as to split principles into more universal principles or more fundamental hypotheses. On the art side it usually consists in experiments made to find a more adequate method of handling the medium, so as to express the artist's vision. Often the apparently unrelated researches are the same down in the depths of the psyche. It has been pointed out that much of modern art is an actualizing in art forms of the same universal invariants as appear in science in the Einstein theory. Human life, after all, is unitary, and we should expect this symmetric dualism in its manifestations. When the crystallizations made by the psyche no longer are useful and do not fit our evolving experience, we have an advance in science. It sweeps away what was called knowledge, and puts it into the museum of discarded theories. Where is to-day the ether which fifty years ago had a density, a rigidity, an elasticity, and was indeed a collection of very contradictory qualities? When the forms used by the artist no longer convey his message, have become lifeless and unsuggestive, we have an advance in art. The daring imagination of Wagner in music gave a new meaning to musical forms. The multitude usually does not welcome these ad-

[1] J. G. Fletcher, "White Symphony."

[2] J. Cheney, "The New World Architecture," p. 347.

vances, for the multitude likes what it is in the habit of having, it resists change, and society in general is conservative. No doubt the first savage to use fire for cooking was accused of impiety, of trying to upset society, of increasing the difficulty of living.

The aspirations of the spirit, however, produce new events in art, and the study of such aspirations is in the end more important than the study of phenomena in the world of nature. Every aspiration has something which may be clasped to the heart and in this way become knowledge, knowledge of life and what it means. When these aspirations which find expression in art forms become organized into living forms, they become visions. These visions have been the dominating forces in the life of man through all the ages, much more than his material environment. Knowledge enables us to secure ourselves against the play of material powers that would destroy us, the frost, the lightning, hunger, pain, illness. But spiritual visions enable us to wish to be secure so that we may expand into flowers that will not perish under the hurricanes and tempests of nature. For a few decades, the study of material phenomena has occupied man extensively, science has become quite powerful, and its success in giving us power to control the world of nature makes it a dominating force in life. But when it undertook to explain the life of art and the spirit, its words were ashes in the mouth, and to-day its finality has vanished.

In his "Dance of Life," Havelock Ellis says: ". . . where we reach the sphere of mathematics, we are among the processes which seem to some the most inhuman of all human activities and the most remote from poetry. Yet it is here that the artist has the fullest scope for his imagination. . . . We are in the imaginative sphere of art, and the mathematician is engaged in a work of creation which resembles music in its orderliness, and is yet reproducing on another plane the order of the universe and so becoming as it were a music of the spheres. . . . The mathematician has reached the highest rung of the ladder of human thought. But it is always the same ladder which we have all of us been ascending, alike from the infancy of the individual, and the infancy of the race. Molière's Jourdain had been speaking prose for more than forty years without knowing it. Mankind has been thinking poetry throughout its long career and remained equally ignorant."

Many mathematicians have said that mathematics is art. Poincaré, Sylvester, Pringsheim, Kummer, Kronecker, Helmholtz, Bôcher, B. Peirce, Russell, Hobson, Picard, Hadamard, and many others, have felt and seen the qualities that beauty shows in the various parts of mathematics. And we may reverse the statement, and just as physics, which was an observational science, ultimately became "the theory of certain differential equations," and at present may be said to have become "the theory of certain linear operators," so art in every line, every phase, every mode of expression, has become the outward expression of certain forms of beauty, simply as sheer beauty. Pure art is as abstract as mathematics. No intention exists of representing nature or man, even in a glorified state. Debussy's nocturnes express sparkling flashes of spiritual insights, Picasso's diagrammatic paintings express designs of the spirit itself. Even if the attempt be futile, as John Gould Fletcher says, the artist must keep on:

> Like spraying rockets
> My peonies shower
> Their glories on the night.
> Towards the impossible,
> Towards the inaccessible,
> Towards the ultimate,
> Towards the silence,
> Towards the eternal,
> These blossoms go.

II. Mathematics

What any art undertakes to do is to give an expression to beauty. In the artist are living, evolving qualities which embody themselves in the art form. The art form once produced becomes part of human consciousness, and on the one hand incites the individual to become a creator himself, at least in a vicarious way, and on the other hand gives him something permanent which he can add to the stable organism he calls himself. At present we will pass over the first phase because we are interested in the second. As knowledge we examine the art form to discover what its structure is. For it has a definite structure, as has everything in the universe. Even if the art form is existent only as music, which passes away with the playing, or as the dance, which ceases when the dancer is still, there is involved in the whole event a definite structure. The static arts—architecture, painting, sculpture, poetry, mathematics—leave a permanent product which may be examined again and again, and the structure can be studied leisurely. But the dynamic arts are birds that must be studied on the wing. They are flowers whose petals expand with the seeing, and then they are gone. Even if they can be repeated, the new expression is never quite the same as the old. Yet they have a structure which is the same. The elements of structure as knowledge in beauty have been named: Rhythm, order, design, harmony. These appear in every art. In the distant future we may expect to find new elements of structure besides these. Of course to be an organism each work of art exhibits these elements as held together in unity. It must be sufficient unto itself. The "Unfinished Symphony" haunts us with wistfulness. In every case the artist brings into being a new creature for the world of spirit; he gives life to it; he watches it enter into his own being, and he may find that it helps him to interpret the riddle of the Sphinx. If we had time we could show that many new concepts of science have had an origin like this.

When we come to consider mathematics we may paraphrase Sandburg and say, "Mathematics is the achievement of the synthesis of hyacinths and biscuits." And we shall find the mathematician more interested in the hyacinths than in the biscuits. Mathematics is engaged in fact in the profound study of and the expression of beauty. The medium used is very ethereal, being pure ideas, nothing material, and this justifies the statement that mathematics is the subtle fine art. Its medium is sublimated to the very limit. It does not depend upon the perceptions of the senses, nor upon matter. No material experiment could have the slightest effect upon a mathematical theorem. The existence of its objects is not in the world of sight. Nature never makes a perfect circle, nor draws a straight line. No fractional numbers exist in her building material, nor is there such a thing as a negative. Kempe defined mathematics as the science of pure form, but this is a somewhat empty concept. C. S. Peirce defined it as the study of ideal constructions. But an ideal construction is a structure. And of what? And by ideal he did not mean abstract, ghostly, purely non-existent.

If now we examine the various parts of mathematics to see what they are essentially, we shall find that they are concerned with the study of these elements of beauty named above; perhaps with particular expressions of the elements, or in the most profound way with the very essence, the spirit of the element in any particular form. In each case there are two phases, one static, furnishing patterns for the element, the other dynamic, furnishing motricities for the element. A pattern is something that remains crystallized, a motricity is

something that parades its life before us. The White Knight said to Alice, "That is not the song, it is the name of the song." Nor is the printed verse the song. The song is gone with the singing. Yet the singing has a flowing pattern which is a motricity. So we have patterns and motricities of rhythm, patterns and motricities of order, patterns and motricities of design, patterns and motricities of harmony. These we find are what mathematics is concerned about.

III. Rhythm

Rhythm is an element of the structure of beauty. But modern physics says that rhythm is the fundamental element in the structure of the entire material universe. It swings around in great spirals the hosts of some island universe distant 300,000,000 light years; it wheels the members of a solar system in their ponderous orbits; it turns the hugest planet like a flywheel; it pulses in the flow of photons of light; it is the heartbeat of the atom; it is the only element of structure known for matter and energy. Wave-mechanics is a new term, but it has become the basic study for the physicist.

When the dawn of intelligence made Eoandros notice the world he was in, he must certainly have soon become aware of the pound, pound, pound, of his overtaxed heart when he had fled the sabertoothed tiger. He must have noticed the rhythm in the beat of the waves on the shore of the lake. He heard rhythm in the call of the crow. Day and night was a persistent rhythm. The flowing curves of birds in their flight, the arrangement of the leaves on the stem of the daisy, the way the petals of the primrose grew, almost all the items of his daily life surrounded him with rhythms. As he developed he began to hold on to certain of these rhythms, and these became knowledge, the knowledge of numbers—at first integers, one, two, three, four, five. In trying to follow the differences in phyllotaxis on a stem he would find fractions, two in five, three in eight. He was beginning the theory of numbers, even though he did not know it. Theory of numbers is still the many-threaded web of mathematics, and is far from being fully untangled. But in essence it is only the study of the structure of pure rhythms. Each prime number starts a new series of ripples, and the list of primes has no end. Do all these waves exist in nature? Apparently not. The imagination of man far outruns the needs of nature. Even the numerous waves of the terrestrial ninety-two atoms occur only in very definite series. These series are quite few compared to the endless list there may be. It was indeed a great source of satisfaction to the physicist when he found out that the series were few in number. His multitudinous chaos is overwhelming enough, even at that. And even when the waves run in packets and simulate particles, the wave-crests furnish only a few rhythms.

Centuries later in the history of man a majestic figure down by the Icarian Sea draws diagrams in the sand. They have all the mystic properties of rhythm: triangles, squares, pentagons, pentagrams, hexagons, figures inscribed inside of figures; then tetrahedra, cubes, dodekahedra, the ikosahedron—even the names are still Greek—all were full of rhythm, and they gave Pythagoras a vision far ahead of his time, a vision of the whole universe as built on rhythm. Number ruled everything, he was quite convinced. And he was more nearly right than was thought until recently. But one dreary day he and his school were appalled to find that there was no rational rhythm between the side of a square and its diagonal. Irrational numbers had emerged and they frightened their creators, and their magnificent temple of rhythm tumbled in ruins around the little band. Little they dreamed of the innumerable arrays of

irrational numbers yet to come, bringing intricate new rhythms. The years rolled on in their cycles, and then one day a rebellious youth named Évariste Galois looked more closely at the irrational roots of equations, and saw rhythm emerging again in beautiful new types. All algebraic irrationals come from certain normal equations, and each normal equation furnishes a flower whose petals are the roots, arranged in cycles and clusters of cycles, of two, three, four, five and so on. The simple flowers of Eoandros have expanded into complicated forms, but with very definite structure for their rhythms. The refractory quintic has been shown to depend on a normal equation of order sixty, but the sixty petals of this flower are arranged in fives, threes and twos, twelve fives, twenty threes, thirty twos, and the transition from one five to another is given by a dance pattern of great beauty. Hamilton playfully embodied it in his Icosian game, its first expression. Irrationals are a creation of the spirit of man, and show forth certain innate rhythms in his own spirit.

But rhythm is not confined to number. For we find that algebraic forms also have their rhythms, and the modular study of these—quite complicated in itself—consists in the finding of these rhythmic relations. An example is the field of symmetric expressions on N letters. Finite geometries also exhibit the same essence. Even in the study of linear differential equations we again discover systems of related functions much like the conjugate irrationals of Galois, for the Vessiot theory is just this in its study of the domain of functions which are roots of these differential equations.

More has emerged, too, than the static arrangements of frozen flowers. For Galois saw that the transitions from one of his sets to another were rhythmic also, and in the place of crystallized patterns we now have flowering motricities. He called them groups in connection with the roots of equations. And these groups, too, we find in a limited number in nature. If we examine the shapes of crystals, we find that they are solids with faces all alike, and the transition from one face to another gives a set of changes which make a group. For we arrive at all the faces from *any* particular one by the *same* set of changes, just as we can derive by the same rational expressions every root of a normal equation from any one. There are only thirty-two types of crystals, however, so the long list of groups is not very much used by nature. Groups of operators they are frequently called. We might set them on a stage and call them dance-patterns.

This opens to us also the meaning of the realm of geometry. It was Klein, in his address at Erlangen, who pointed out that every type of geometry was a listing of what did not change in the transition from one figure to another under given conditions. Projective geometry with all its beauty is one of these systems of rhythmic change. Inversion, geometry, conformal geometry, and other Cremona geometries are also examples. The bewildering arrays of forms begin to come into order and their relations are easily apparent.

But we have still more extensive riches in the motricities of rhythm, for we are now in the field of linear operators, with their fundamental functions. This gives us the power to handle wave-mechanics, and in fact wave-mechanics is in essence the study of the rhythms of the so-called ψ-functions of modern physics. But again what the mathematician studies is infinitely more than the physicist can use. The creative ability of the spirit of man finds its outlet in the creation of ideals. And in the process much knowledge which was considered valuable is swept away, for that which in modern times is worth saving in these outflowerings of the spirit is

more far-reaching in its usefulness, more condensed, more generalized, more suggestive.

IV. Order

Another element in the structure of beauty we call order. Order was early in its appearance to man. When he studied a square, he found that all the angles at the corners were alike. The diagonals had the same length. They crossed each other, making angles like those in the corners. Also, if he made squares on the three sides of a right triangle, that on the hypotenuse could be made exactly out of pieces of the smaller squares on the sides. Diagram after diagram was investigated, and the collection of theorems they found was put together by Euclid. Geometry it was called, for it could be used in surveying. But this practical side was scorned by the real artists. When a student who had learned a new theorem in Plato's Akadême asked what use he could make of it, the master called a slave and said: "Give him two-pence, since he must make money out of what he learns." They considered the various forms of order they discovered as sacred, and not for the common herd of human cattle. These subtle connections in figures became more and more elaborate as time passed. Perhaps we should end the Greek geometry with the investigation of Apollonius on the figure made by circles tangent to three given circles. When another young French genius, named Pascal, discovered the famous theorem bearing his name, he had an order which includes all the properties of conic sections. If we select any six points on an ellipse and number them in any way, 1, 2, 3, 4, 5, 6, then join 1,2 and 4,5 and find where the lines intersect, then 2,3 and 5,6, and find the intersection, and finally 3,4 and 6,1, and find the intersection, the three points of intersection will always line on a straight line called a Pascal line. Since the six points can be numbered in sixty different ways, there are sixty Pascal lines. These go by fours through forty-five points called Kirkman points, three on each Pascal line. The diagram becomes more and more complicated. And we could have used a circle or a parabola or a hyperbola or even two straight lines in a plane, instead of the ellipse, with like results.

There is order of course in any vision of an artist. If we put together tones we find both horizontal and vertical orders for them. We study this in counterpoint. If we examine an abstraction of Picasso's, the colored triangles, rods, violins and other forms have an order which is the real essence of the picture. Stravinsky's compositions might seem chaotic, but they have a subtle order. Any system of theorems about the products of art may be called the list of order patterns found.

Man reached beyond the world of sense again in this region, too. For the puzzling parallel axiom ultimately led Lobatchevsky to try to see where the contradiction would enter if he made a geometry in which this assumption was left out. The result was startling, for much to his surprise and delight, he created a new world. One non-Euclidean geometry had been born, and now there are many. It was found that psychologically we are built on the non-Euclidean plan, and the very simple constructions of Euclid were utterly non-existent for our senses. Many painters unconsciously make use of this now in what looks like queer perspective and outlandish arrangements. However, they are giving visible form to ideas in order that express new visions of beauty. In music, the drama, the dance, we find it also. And even in poetry non-Euclidean arrangements seem to be necessary. Gertrude Stein has experimented with many.

We go further, however, for man is not contented with the order he gets from a two-way system or a three-way

system. He has created four-dimensional geometry, and even has dreamed of a universe for himself which is four-dimensional. He tries to put length, breadth, thickness and depth into one figure. At any rate, in architectural ornamentation Claude Bragdon has shown the beauty in traceries that depend on four-dimensional order. The relativity theory at first tried to coordinate space as we see it, and the flow through time as we feel it, and thus have a four-dimensional space-time world. In such a world every human life would be a complete, finished, predetermined, static thing. Our appearance in the world of others would be like the figure made on the surface of a pond, if we should gradually and smoothly draw up a solid object from the bottom of the pond. And if four dimensions, let us also have five, six, a million, an infinity.

Then, too, these order-relations do not have to be seen in space forms. We can find them in algebraic expressions as related to one another, and it was a brilliant day for the mathematical artist when Descartes said, "Geometry and algebra are one." Indeed, most geometry to-day is the study of algebraic expressions, in a geometric language. As an example of algebraic order, the product of sums of two squares is the sum of two squares, the product of sums of four squares is the sum of four squares, likewise for eight squares.

If we pass from the patterns we find for order, to the motricities, the flowing types of order, we also have inexhaustible riches. We call these "algebras." When Hamilton saw four worlds of rhythms, arranged in the quaternion algebra, the human spirit had been liberated into an entirely new universe. Equations could now have not only the flower-clusters of Galois as solutions, but each petal itself became a new world, and there were flower-clusters of universes. Every equation now has but one root, very complicated it is true, but unity has been restored to the theory. And unity is one of the essential elements of beauty. These hyper-algebras have been found in the last decade in the problems of physics, and indeed without hyper-algebras physics would not have solved its problems even in the partial manner they have been handled. In the simple case of complex numbers, Steinmetz pointed out that alternating theory could be brought into unity with direct theory in their laws, by considering that each current, electromotive force and impedance was really a single complex entity and not two independent entities. It is complex algebra that slides along a power line, or sings in the radio. And hyper-algebra vibrates in the levels of the spectral lines which come from Arcturus, Sirius or Antares.

The artist who combines music and mobile-color or music and the dance is a hyper-algebraist. Color and tone are two qualitatively distinct rhythms, as are tone and motion, neither can be turned into the other. To unify a composition which puts them together depends upon the synthetizing ability of the human spirit to make a unit out of the expression and is to work in hyper-algebraic relations. The modern synchronic arts try to do this difficult thing. If they fail occasionally, that means nothing. The problem is to succeed even once. Then, if we combine music, mobile-color, the dance and poetry, we have indeed a four-dimensional world to live in, and the possibilities of subtle art expression are unlimited. We get visions of beauty and of infinity and of eternity. Ruth St. Denis consciously, or unconsciously, has some such vision as her guiding star. In mathematical forms, however, each dimension may be turned into any other. And this is the complete triumph of this mode of art.

V. Design

Another element in the structure of beauty is design. This is the arrange-

ment of things, the way they are combined. The series of colors in the rainbow is a design. The stars of snowflakes are designs. The frost gardens on the window-pane are designs. We find a design made up of repeated elements which are alike, as the ripples that play over the surface of a lake, the many spirals of the pine cone, the call of the whip-poor-will. Or we may find a design in the fading terms of an arithmetic series. Design may be combined with rhythm, either periodic or cadenced. Or design may occur in a continuous series. The tangent lines of a circle constitute a design, the definition being that each is at the same fixed distance from the center. The Grand Canyon is a design, so is the Painted Desert, and so is the uranium atom. Clouds execute designs that may float across the sapphire sky, or they may wind like wraiths through the canyons of the mountains. Cloud shadows make designs across the slopes. And in Georgia O'Keefe's wonderful designs the flowing rhythms of wind, water, flame and mountains constitutes the picture. The label is of no importance. In the brilliant diagrams of Kandinsky color-design is the prominent feature. The statues of Archipenko are designs, not portraits, and in a large collection of mathematical models of surfaces, we may find statues much like those of Archipenko. When we divest our art form of the representative character, do not try to imitate objects, undertake in short to be abstract artists, then we can see design more easily. In the American Indian art we have come to appreciate this kind of design, often of high order. In sheer music we have abstract design perhaps for our day at its highest. Abstract art as it is to-day is an emphasis on design, whether it be in John G. Fletcher's poetry, in "Pelléas and Mélisande," in the marvelous dream of Eliel Saarinnen for a city building, in an abstraction of Duchamp-Villon, in Russell's Synchromie Cosmique, in a composition of mobile color, in the Fire-Bird of Stravinsky, or in an abstract dance—poetry and music in motion—in all these we find or should find design. In many branches of mathematics we are studying purely the structure of design.

If we consider the points of a circle we have a design of points, so for any locus of points. If we consider the tangents of an ellipse we have a design of lines, and so for any envelope. The description of the design may be very brief, as in the differential equation $ydx - xdy = 0$ we are merely saying: Draw all the straight lines in a plane that go through a fixed point, like the spokes of a wheel. In the equation $ydx + xdy = 0$ we are saying: Draw all the equilateral hyperbolas with two given perpendicular lines for asymptotes. In the equation $xdx + ydy = 0$ we are saying: Draw all concentric circles with given center. In the differential equation $(y - px)^2 = \frac{c^2p^2}{1+p^2}$ we are saying: Draw the lines which will always have a fixed amount cut off between the coordinate axes. They are the tangents of the astroid. In polyhedra we have designs, as the polyhedra whose faces are equal equilateral triangles, which may be the regular tetrahedron, octahedron or ikosahedron. If the faces are equal squares, the figure is a cube. If they are equal regular pentagons it is the dodekahedron. In case the faces are equal rhombuses, we have the rhombic dodekahedron or the triacontahedron. In the undistorted crystal, we have polyhedra whose faces are all alike. There are thirty-two large classes with many special cases. All the Archimedes polyhedra are designs. If we make a design by repeating the elementary crystals, as does nature, we find some 230 lattice forms.

If we turn to arithmetic, we may

study congruences, which are designs, in which all integers are arranged according to their remainder when divided by the module. With twelve as the module, there are twelve residue systems, and of these four, namely, those of one, five, seven and eleven, constitute a special system called the totitives of twelve. Their products will always be totitives, and the list may be generated from five and seven alone. The designs in theory of number become very elaborate. Higher number theory is on the frontier of mathematical evolution. We may take congruences of algebraic forms in the same way. If the module is x^2+1, then the residues are all numbers, all multiples of x and all forms $ax + b$. If we combine them we call them "complex numbers." All numbers of a residue class are equivalent.

If we turn from design patterns to design motricities, we find plenty of examples. The musician creates a fugue, which is essentially a design motricity from a theme or themes to the various forms they are to appear in. If a painter repeats a triangle in differing colors and shapes, he has a design motricity. It is not the shapes and colors that are important, but the change from one to another. Hebrew poetry is largely a motricity design, enunciating a statement which is repeated in different forms to give new suggestions:

> One that ruleth over men righteously,
> That ruleth in the fear of God,
> He shall be as the light of the morning when the sun shineth.
> A morning without clouds;
> When the tender grass springeth out of the earth,
> Through clear shining after rain.

In transformation groups we find motricities, and any mathematical process of combination is a motricity design.

New designs appear in the development of any art. For instance, in music there were tones, then the tonic, the dominant, the subdominant, the major chord, the minor chord, augmented triads, diminished triads, counterpoint, dissonances. The painter learned how to make color vibrate, and even tried to show motion, as in the famous "Nude descending a staircase." In the dance a new expression for the mystic's ecstasy was created, and the rapture of the worshipper of beauty. In mathematics were created non-Archimedean number, infinitesimals—the monads of Leibniz—algebraic fields, automorphic functions, discontinuous functions, nilpotent algebras. What must be created next is a mathematics of consciousness, a theory in which x does not represent a range of values but a range of overlapping moments.

The general theory of rhythm is abstract arithmetic and abstract groups; the general theory of order is abstract geometry and abstract hyper-algebra; the general theory of design is abstract tactic and abstract algorithms; and for the next element, the general theory of harmony is abstract logic and abstract dialectic.

VI. Harmony

We consider the fourth element of the structure of beauty—harmony. On the purely knowledge side it is called consistency. Those harmonies in ideas which we perspicate as worth preserving we call propositions. From these we arrive at concepts, relations, classes, and as one of the very large branches of mathematics—logic. So important a part is it that in 1901 Bertrand Russell went so far as to assert that mathematics is symbolic logic. And for some two decades this simple assertion was so pleasing to the esthetic sense of mathematicians it was often adopted as the final statement of what mathematics is. But the statement has been shown so often to be inadequate that new definitions have been expressed. Indeed, it

is so far incorrect that we must assert that in place of mathematics being logic, symbolic logic is only one phase of mathematics. This is all the more evident when we look at the new logics created in the last decade. "To be or not to be" is no longer the list of possibilities, for it must read now, "to be or not to be or to—what?" Brouwer's work along these lines is very new, and not yet widely read. We still do not consider as harmonious being and non-being, but as a choice between them there are other alternatives. The dichotomy and law of excluded middle of Aristotle, which held the world so long in fetters, are now seen to be but one way of thinking, and the human spirit is creating new ways. What this may mean philosophically is for the future to work out. The law of identity too is gone, and no thing or event is ever again what it has once been. The saying of Heraclitos many centuries ago is seen to be true: "I can never step into the same stream twice."

Consistency is in a curious situation, for there is no test, no criterion, of consistency. We have not noticed so far any inconsistency in ordinary Euclidean geometry, for an instance, but what the future may bring forth we do not know, and the entire structure may some day be seen to be consistent only under conditions not yet stated. There is no criterion for harmony either. What is inharmonious to one age or one people is harmonious to another. Even Schoenberg's dissonances produce a harmony not thought of before. The universe in short is evolving, that is, changing from time to time, and place to place, and man is evolving and acquiring new intuitive power. Indeed, we find the solutions offered by poets, prophets and artists for the desperate problem of evil are solutions which practically say that there is really only harmony in the world and what we call evil is a kind of harmony we have not yet come to see through. It is part of a design we do not comprehend. But harmony was recognized away back in Pythagoras' time as one of the most desired goods; indeed, he says that when we appreciate harmony we shall become as gods.

That we can learn to see deeper harmonies we might exemplify in this way. If we consider a circle, we see of course that every point on it is at the same distance from the center as every other point. This is harmony. But if we project the circle, that is, take its shadow as it is held in different positions in front of a brilliant point of light, the circle becomes an ellipse or a parabola or a hyperbola, and the center becomes a point which is no longer center for anything. The harmony remains, however. The trouble is with our first statement. For if we avoid the word distance, and substitute terms from projective geometry, the center being the pole of the line at infinity, then we see that all statements remain unchanged. If we call the center the intersection of conjugate diameters, the new statement is the same. The harmony remains, but it must be seen from a more exalted standpoint.

We must consider harmony motricities too, and on the consistency side they are the modes of inference we use, the patterns of deductions, whether ordinary inferring or such subtle inferences as those Fermat used so effectively three centuries ago. The essence of these, commonly called "mathematical induction," is simply the intuition of that part of a set of particular facts, which remains independent of other parts. To use James's example, if I say that on a Royal Baking Powder can, the wrapper has a picture of a Royal Baking Powder can, then I know at once that inside that is another picture, and another, and so on to any extent. Or again the lines that connect in succession the midpoints of

the sides of a rectangle make a rhombus, and the lines that connect the midpoints of the sides of a rhombus make a rectangle; therefore, if I continue drawing such lines I will forever have a rectangle or a rhombus. The edges that join the centers of the faces of a cube make an octahedron, and the edges that connect the centers of its faces make a cube. Hence the conclusion. But we can go further, and state that in a certain figure we have drawn with yellow crayon and labeled an isosceles triangle, the equality of the sides demands as harmonious the equality of the two base angles. And since this fact is independent of the size of the triangle, or its particular shape, or its color, we may say that in any isosceles triangle the base angles will be equal. It is easy to see that most mathematical reasoning is of this intuitive and we may say, Fermatian character, which was pointed out some years ago by Poincaré.

As an example of what is meant here by harmony motricity we can cite the symphony in music. It is a composition of many parts, very elaborate sometimes, yet all in harmony. In grand opera we have another example. The theory of rational mechanics is another case, very largely ideal, and treating of situations, forces, and laws not known to exist in nature, but so harmonious a system that physicists were very reluctant to dispense with it, and even yet cling to Hamilton's principle as the one key to all modern relativity physics.

One of the most magnificent attempts at the production of harmony in mathematical subjects is shown in the late E. H. Moore's "General Analysis." For several years he worked on this unifying theory, and in the course of time all his researches will be published. It brings together in a mathematical symphony every part of analysis, so that we deal with a finite number of variables, a denumerable number, or a non-denumerable infinity, all at the same time. It uses matrix theory for explaining any type of integration; and rationality domains, hypercomplex domains, functional domains, all appear to play their rôles.

VII. Conclusion

We now return to the original question: What is mathematics? We are able to say that in the spirit of man, a living, constantly changing, elusive entity, there are elements which produce art and knowledge. If we study what they produce, we find that it is called beauty, and contains elements which we may consider either from the living, dynamic side as elements in the structure as viewed by the artist; or we may look at them from the static side, as knowledge, and name them rhythm, order, design and harmony. Mathematics is, on the artistic side, a creation of new rhythms, orders, designs and harmonies, and on the knowledge side, is a systematic study of the various rhythms, orders, designs and harmonies. We may condense this into the statement that mathematics is, on one side, the qualitative study of the structure of beauty, and on the other side is the creator of new artistic forms of beauty. The mathematician is at once creator and critic, not always, of course, in the same person. It is well known that Sylvester, Klein and Poincaré were great creators, and not much interested in the critical side. Cayley, Hilbert and Picard were magnificent examples of the critical side. Sylvester never knew in a new set of lectures where he would go. Klein was the despair of Hilbert with his flashes of intuitive creation, using any medium for expression that met his fancy. Poincaré always attacked his work with the intuitive eye. But in all great mathematicians from Pythagoras to Poincaré we find the artist character combined in varying degree with the scholar character.

We may also now answer the second question: Why should mathematics interest more than a few? Mary Austin in her "Everyman's Genius" advises all creative artists to study higher mathematics, so does Havelock Ellis. Not of course for the mere scholarship involved, not for the keen intelligence it will promote, but for the high order of imagination it will demand, for the incisive artistic insight it will generate. If, for instance, one studies only the fields in algebraic number which are superquadratic, having groups of order 2^N, he will learn new things about beauty. If he studies only the field of symmetric algebraic forms he will be charmed with its elegant beauty. The algebra of determinants is a beautiful garden, open on every side to expansion, as one may see in Metzler's treatise. If he finds some new theorems in the geometry of the triangle, he will be thrilled with their beauty. Merely to know of the transversals of a triangle, the Brocard points and Brocard circle, the Lemoine circle, the nine-point-circle, the Tucker circles, the isotomic lines, the isogonal lines and other figures, will bring new beauty to the imagination. In theory of numbers Fermat's last theorem awaits its proof, and will crown with glory the one who gives the proof. Dickson's division algebras furnish a very interesting and profitable realm for new theorems. Why extend the list? It is endless.

Many mathematicians have been artists in other ways. Some wrote poetry, some composed music. The inquiry conducted several years ago into mathematicians' activities found that most of them were seriously interested in some phase of art. And most of them reported that their discoveries or creations came just as do the inspirations of artists in other lines. The mathematician dreams, and in his dream an elusive spirit goes in and out; floats in the mist, and vanishes; glides back at unexpected moments, but slips away from the hand that would grasp her; reappears in an intricate dance, and phantasmal play of color; disappears; and one day steps out to clasp the hand that has awaited her, with Kummer's ideal numbers for a gift. The mathematician dreams and in the spinning chaos fairy flowers in fantastic forms bloom and vanish; mists wind through them with birds flashing now and then; strains like Debussy's nocturnes are faintly heard; a seething, bewildering multitude of forms are created out of the void, they drop back into the void; and then in one rapturous moment a new form appears, superbly beautiful, and Prospero's wand is held stationary to bid the cloud-castle, the flowers, the wild birds, the haunting music, the spirits of light and beauty stay, and a new branch of mathematics is born, the linear associative algebra of Benjamin Peirce. This is an enchanted land, and the city, like Hugh Ferriss' "Metropolis of Tomorrow," is, in Tennyson's words, "built to music, therefore never built at all, and therefore built forever." It is a world that knows no second law of thermodynamics, a world that guarantees to man his creative nature, his eternity of time, his imperishability. Here grows the ash-tree Yggdrasil, supporting the universe, its roots in nature, its trunk of the fibers of logic, its foliage in clearest ether of intuition, its inflorescence the living imagination. In this land of enchantment the queen is beauty, who turns men into gods.

ROMANTIC GOVERNMENT VERSUS UNROMANTIC GOVERNMENT

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THE human animal is an incurable romantic. Other animals seem to view life rather objectively, taking it as it comes and for what it seems to be, but man prefers to view it subjectively, painting it over in his favorite gay or somber colors, dramatizing it, and in one way or another transforming the spectacle and action into something befitting the animal which lives at the center of the universe and is the most important of created things. Through his animistic romanticism he achieves his religion, by chivalrous and gallant romanticism he elevates passion or the routine of marriage to the status of love, and by an admixture of hero worship and fetishism he formulates his governments.

This passion for romanticism in our personal life has some desirable aspects. In its religious phases it has taken form in some commendable ethics and some noble architecture, painting and sculpture. In the field of individual emotions, it leads to pleasant relationships and the works of Lucian and Cabell. In personal matters, the right to romance and romanticism is well within our circle of personal rights. But in government romanticism expresses itself, only too clearly as regards the comfort and safety of mankind, in democracy, autocracy, aristocracy, dictatorship and similar romantic ideology.

It must be admitted that in all probability the romanticism which has colored all government from ancient times to the present was and still is inevitable and inescapable. The reasons for a human behavior that is world-wide and rooted in the ages must be real, profound and convincing. But at this time I challenge the necessity for continuing to regard government from a romantic point of view.

From the romantic point of view, government is a matter of politics, statecraft, diplomacy, principles, tradition, leaders and similar components. All these things can be defined objectively, and all are rich in connotation and prone to arouse warm emotional reactions. To one man democracy is a fetish, and dictatorship an abomination; to another man dictatorship is a fetish, and democracy an abomination. Such emotional reactions have carried governments through alternate cycles of one thing and another, but there is little profit in the alternate testing and disapproving of this and that.

It is proposed here to examine the concepts of government somewhat briefly and critically, not to settle anything whatever, but to present a point of view which is seldom utilized in considering governments. Briefly, we think that governments are not good subjects for romantic treatment, that romantic ideas of government obscure facts that are self-evident except to romanticists, and that an existing move towards unromantic government, a move not generally recognized, should be given consideration as offering something more fitting for modern times and present-day needs.

To make clear the distinction between romantic and unromantic concepts of government and to provide a background for discussion, we define unro-

mantic government as the conduct of the communal business, government that attends to such business as is not attended to by individuals or non-governmental groups, such business as the commonplace routine of public works, roads, taxes and public health. If we look at government in this light, we can regard it as a matter calling for the employment by the state, whether the state be federal or town in scope, of persons well informed and well trained in such subjects as public works, roads, taxes and public health. This simple and unromantic view of government is remote from the accepted views, and we proceed to take issue with those views.

One of the romantic elements of government is the entire concept of politics. It finds romantic expression in the American devotion to a two-party system, supposedly expressive of the Gilbert and Sullivan concept that "Every boy and every gal that's born into the world alive is either a little liberal or else a little conservative." How true this concept of a right and left wing may be can be judged by the national political platforms of our leading parties in 1928, when the left wing, not unnaturally, proved to be a mirror image of the right wing.

The romantic American sees nothing incongruous in selecting as mayor of a city a Democrat or a Republican at a time when a Democrat is defined as a believer in tariff for revenue, and a Republican as a believer in a protective tariff. Obviously, one's tariff beliefs have nothing to do with judging whether Main Street should be repaved, nor does a mayor vote on tariff legislation, but to the romantic American that does not matter.

Romantic government deals in emotionalism, in patriotism exemplified in ritual, ceremony and formula, in international hatreds, in the reform of its citizenry by Mann. acts, Volstead acts and similar noble experiments and acts of faith in unbelievable things.

The smart politician is not in the least deceived in this matter. Voters may think that there is a principle at stake in local elections on a national party basis, but the shrewd politico knows that the thing at stake is the question of who gets the office and influence, and, too frequently, who gets the concessions, graft and other perquisites. The smart business man realizes that in a world of romanticists government will control business or business must control government, so he and the politician have an understanding from which romanticism is eliminated.

Another priceless pair of romantic concepts is that of statecraft and diplomacy. These elements of grand strategy are eternally conjoining with the military forces to seize some Alsace-Lorraine and thereby sow the seeds of new wars, all of them destructive to winner and loser alike. Their smartest achievements of to-day are seen in some not remote to-morrow to be stupid and vicious, and it is difficult to find in the long list of statesmen and diplomats any whose judgment and achievements have had historical justification.

Traditions are the special heritage of romantic government. Many of them are immensely valuable to the stage, the movies and literature, since it is undeniably fascinating to find in such places as London the endless picturesque doing of elaborate things for no reason other than that these things were done a thousand years ago for reasons long ago forgotten or no longer applicable. As a spectator one can approve these things almost whole-heartedly; as a citizen one could ask that they be transported from the field of government to the field of histrionics, where they belong. Traditions ennoble not merely the gaudy and useless, but also the preposterous and iniquitous. They tie us with the fetters of dead men, dead beliefs, dead emotions. They close the avenues to change, experimentation and progress, and force

on the unromantic element of government the rôle of iconoclast.

At this time the world is in a mad search for leaders, and the supply of leaders is, as usual, quite equal to the demand. Leaders are such a simple solution for a lot of baffling problems. They answer all the moronic demands of bewildered minds for a Moses to lead them to some Promised Land, for a magician who can solve all problems, national and international, by the magic of personality and leadership. It is a comforting idea to romanticists, who find that thought is conducive to headaches, and hard work productive of backaches. The history of the world's leaders shows that if the mob will follow, leaders will lead them somewhere, but not to the land of heart's desire. A Peter the Great may learn ship-building and lead in that art a people that are not ship-builders, but in general the political romanticist wishes nothing so simple and so difficult. He wishes leaders of an inspirational sort, who by inspiration know the answers to the questions of tariff, coinage, transportation, communication, immigration, international trade and such bagatelles of government. The realist in government does not wish to be led; he wants trained, capable, intelligent, honest public officials who will attend to the public business.

Among the romantic concepts of government is democracy. Democracy is too valuable to be subjected to the fetishistic treatment of romanticists, for this sort of treatment endangers the existence of realistic democratic government. Democracy has this valuable characteristic: It ensures individual safety as no other forms of government have ensured it, and on that one score alone democracy should be saved from its friends and its foes alike. It is notorious that democracies have often proved inefficient, but thousands of years of dangerous autocracy of one sort and another have driven nations to democracy. All Latin America knows that when dictators have destroyed the machinery of democracy elections must be by revolution, and that revolutions are the inevitable sequel to dictators.

Nevertheless, we have the swing to the romantic concept of the ancient cult of the dictator, the Man on Horseback. It is astounding to have in modern times this recrudescence of belief in the Able Man, with its flavor of divine right of kings, of the law of lése majeste, its suppression of opposition, criticism, alien groups and the like. To a realist there is nothing surprising in a band of vikings hailing as leader their best fighting man, for theirs was a government that dealt in war; these men were realists, the greatest warrior was their expert in government, and he gave them precisely what the realist wishes, expert government. To-day, the dictator is an anachronism, the skeleton of an ancient realist dug up by romanticists and set to rule over romanticists. Your hero worshipper has the faith of all romanticists, the faith that a dictator can know all the complex business of government. To a realist it seems evident that dictators are too small for the large job of government, and too impermanent for its long-time needs.

It is said that dictators are efficient. To this assertion the realist may cock an incredulous ear. It is admitted that dictators have the unimpaired authority to do things that their title implies. It is admitted that they do the things they wish to do. But it is not admitted that doing what one wishes to do is efficiency. A child may break its toys quite painstakingly, and not be efficient or admirable. Efficiency in government implies not only that things are done but that these things are desirable things and are for the general welfare. On any such basis we note that dictators, unpredictably, may do preponderantly good things, or preponderantly bad things,

or, as in the case of Napoleon, may balance a Code Napoleon and some good roads against devastating wars and "forty battles won." On the whole their record of efficiency is little, if any, better than that of democracies. Against any efficiency dictators may exhibit, we set the fact that the dictator is dangerous to the life, liberty and happiness of the citizens he governs. He imposes on them the necessity of agreeing with him or suffering, a thing for which only a romanticist can hurrah; your realist in government, who believes the whole greater than any of its parts, finds this a droll concept of a government attending to the communal business by molding a nation in the form of one of its citizens. One can see the workings of a dictator to very great advantage in the small-scale operations of a Latin-American country, and having seen it on such a small scale the realist will not wish to see it on a larger scale. The romanticist, of course, will continue to find Diaz of Mexico, Emiliano Chamorro of Nicaragua and Machado of Cuba admirable dictators, just as he finds Caesar, Tamerlane, Napoleon, Mussolini, Stalin and Hitler admirable dictators. As individuals these men may have great charm and ability, but the unromantic realist will look askance at all dictators as dictators.

As a realist in matters of government, I speak now for unromantic government. For a quarter of a century I have participated in the unromantic government of the United States, and, at the same time and at close range, have been a spectator of the romantic government. During that time romantic government has been represented in the White House by the strenuous Teddy Roosevelt, the judicial Taft, the scholarly Wilson, the genial Harding, the calm Coolidge, the engineer Hoover and Franklin Roosevelt, whom history will characterize better after all the returns are in. It is sufficient to name these men, to recall their characteristics and the manner and reasons of their accession to power, to see how romantic government functions. Do you recall how up to a certain March fourth, each of them was to almost half our citizens the embodiment of all objectionable things, and how after that certain date each became imposing, oracular and incredibly important? This is magic, the magic of the romanticists.

And in the same period, who constituted the unromantic government? During that period the unromantic government consisted of bureau chiefs, division chiefs, editors, scientists, physicians, veterinarians, lawyers, officers and men of the army and navy, clerks and other workers. You probably know little about the personnel of this unromantic governing group, but you may recall Goethals, Gorgas, Reed, Carroll, Asaph Hall, Peary, Byrd, Stiles, Walcott, Stratton, Galloway, Taylor, Mohler, Harvey Wiley, Gifford Pinchot, L. O. Howard, Goldenweiser, Durand or Atwater as some of the distinguished representatives of unromantic government.

And what did these realists in government do? They proved that yellow fever was carried by mosquitoes, they drove yellow fever from the Isthmus of Panama, and they built the Panama Canal; they lessened the incidence of amebiasis, malaria and hookworm disease; they developed high-frequency radio communication; they gave over 5,000 bearings a month to merchant ships to make navigation safer; they devised the sonic depth-finder for rapid surveys of ocean depths; they invented smokeless gunpowder; they provided precise time for surveying, astronomy and gravity determinations; they published the *Nautical Almanac* and *American Ephemeris;* they conquered the North Pole and the South Pole; they brought relief to sufferers from pellagra and Rocky Mountain spotted fever; they developed the anticlinal theory and the

carbon ratio theory for the use of the petroleum industry; they devised a system for the blind landing of aircraft; they supplied data for ventilating the Holland Tunnel; they built the tide-calculating machine which, with one operator, does the work of 70 mathematicians and saves $150,000 in salaries annually; they developed disease-resistant plants; they introduced durum wheat into this country; they synthesized ammonia directly from hydrogen and nitrogen to make fertilizers; they developed control measures for dust explosions and lowered insurance rates; they found a method of making furfural for 10 to 17 cents a pound instead of $30 a pound; they found that Southern cattle fever was carried by the cattle tick, and they drove the tick from over 89 per cent. of its range and are driving it from the parts of those states where it makes its final stand, saving $40,000,000 annually for a total cost of less than $40,000,000; they developed a treatment for human hookworm disease, and for hookworm disease and heartworm disease in your dogs; developed the hog cholera serum which saves millions of dollars worth of swine annually; they protected you from adulterated foods and inert drugs; they inspected your meats; they compelled the adoption of safety devices on railroads, ships and airplanes for your protection; they supplied expert information on finance, tariffs and similar subjects; and in a thousand ways they carried out the communal business, the work of the United States Government, the unromantic government that is overshadowed by the more gaudy and vocal romantic government.

The personnel of this unromantic government is selected by Civil Service competitive examination on the basis of education, experience, training and knowledge. Any one of several qualified persons at the top of a list may be appointed to a position, but all these persons are qualified. Compare this with our romantic government, elected on a platform of ballyhoo, favorite sons, stupid slogans, election promises, vilification, innuendo, such magical cantraps and abracadabras as will most certainly enchant the romanticist, and such doodads, dingbats and thingumabobs as will delight the grown-up children. Does this system secure qualified persons? Perhaps it does in your party, but it quite obviously does not in the other party.

The unromantic government is expert government. In the list of names given here are many of men who are rated as the best or among the best in the world in their field. Most of them had this rating when they were being paid from $1,400 to $5,000 a year. How many Congressmen selected on the romantic basis of politics are the best or among the best in the world in their field? How many have an expert rating in any field? Offhand I recall a few, such as Senator Copeland, an expert on public health, this rating dating back to the days when he was part of New York City's unromantic government, and Senator Glass, an expert on banking.

But, you may ask, what of it? We have two kinds of government; granted. So what? I answer: Why not abolish the romantic methodology and substitute the unromantic? How? Continue to substitute the professional non-political type of government for the political non-professional type, and keep on until the professional type is carrying on all the nation's business instead of sharing it with the political type. How could this be done? By the extension of a sound civil service or other merit system, gradually encroaching, as it has in the past, on the field of the spoils system, of the political henchman and of political nepotism, until romantic government is replaced by unromantic government. We should lose nothing from our romantic selections except the incompe-

tents, as the competent would be more certain of selection under a merit system.

Does this seem difficult? It is no more difficult to hold a Civil Service examination for a sheriff than for a geologist, for a judge than for a psychologist, for a congressman than for an economist, for a president than for a sociologist. Let us grant that you can name a half dozen presidents, selected by romanticist measures, whom you regard as highly competent presidents; you can also name a half dozen whom you regard as highly incompetent. Unromantic government would retain all the safety of democracy by allowing the electorate to vote for presidents, but would eliminate the inefficiency of democracy by limiting the candidacies to qualified candidates only, so that regardless of who was elected the president would be a qualified person. Such a system would not get ideal executives, but it would eliminate preposterous persons from the presidency, governorships and mayoralties. It would ensure that judges were competent in judicial matters, and that legislators knew something of law-making and were never elected merely as good fellows, handshakers and donors of cigars.

The objections that will occur to you are easily foreseen. Some persons without education, training or experience, but with qualities of leadership, would be disqualified. However, the unromantic realist will refuse to weep if there is never again a Jackson in the White House. Jackson fitted his era, but the era is over and we face complicated problems through which no amount of hard-headedness can butt a way. Courage alone will not solve banking and monetary problems.

Another objection is that this unromantic government is merely bureaucracy under another name. There would be good grounds for this objection. Bureaucracy is government by bureaus, according to definition, and on this basis you have bureaucracy already, since a half million persons, from admirals, generals and bureau chiefs to the doughboys, gobs, mail carriers and messengers, quietly carry on your bureaucratic government twelve months in the year, while your romantic government puts on its lesser and noisier show for a small part of the year and then joyfully rushes home to take up its more serious occupations.

But bureaucracy may have an unpleasant connotation, and this unpleasant term is defined as officialism with officials endeavoring to concentrate power in their individual bureaus. Speaking as a bureaucrat, in the sense of an officer in a government bureau, I note that in the government bureaus one finds about the same variety in ambition that one finds elsewhere, some officials being satisfied with small organizations and some desiring large organizations. There is little damage evident in either case, but it is evident that a too small organization may be inadequate for the demands made on it, just as a large organization may be too large for the demands on it.

But, you may say, bureaucracy implies officiousness. Admittedly, we occasionally meet with officiousness, usually on the part of lesser and relatively unimportant persons, among bureaucrats as among bankers and ribbon clerks. Officiousness is a nuisance, and nuisances are objectionable. But if we weigh the nuisances of our unromantic government against the dishonesty of some romantic administrations, the stupidity of some others and the danger from fanatical legislation in some others, we must see the officiousness of a minor bureaucrat as the least of the evils named.

In the high but not so far-off days of the spoils system, when all American politics was romantic politics, one section of the government service was known as The Harem, and there were

Congressmen's lady friends who were paid as artists, although they never drew anything except their salaries. Finally, a disappointed office-seeker shot a President, and a Civil Service that should have been born earlier of common sense and realism was born of anger and grief. The political romanticists provided that the unromantic government it had created must keep out of the romantic side of government. Why? Because political romanticism was ruinous to efficiency and unbiased honesty. It was not noticed at the moment that political romanticism is quite generally ruinous to efficiency or honesty or both, and not merely in the civil service. It is, of course, as ruinous in a legislative body as it is in a scientific laboratory. A really able legislator, La Guardia, has said: "The most humble research scientist in the Department of Agriculture is at this time contributing more to his country than the most useful member of Congress." If this is even partially true, it is because the selection of legislators on a romantic basis can be depended on to turn up very few La Guardias, whereas a merit system of selection, such as the Civil Service, can be depended on to turn up qualified persons with great regularity.

By virtue of the prohibition of activity in the field of romantic government, and by virtue of residence in the District of Columbia which deprives them of their right to vote and ensures that they will be taxed without representation, the Washington representatives of our unromantic government may be said to have been deprived of their political rights. Now, there is no fetish more dear to political romanticists than political rights. Undoubtedly they are important. But just what are our political rights? Are they what the political romanticist thinks they are? Are they the right to shout and write for this, that or the other action on subjects of which the romantics know little or nothing, and ultimately to vote for persons with whom they agree and who likewise know little about these subjects? Apparently they are just these things. And is this important or valuable? Was all the oratory and ink that went into the McKinley-Bryan campaign of 1900 of any more value and benefit than the concurrent debate as to whether the century began in 1900 or 1901? Was all the Coolidge-Davis debate and controversy of more importance than the question: How old is Ann?

There are certain personal rights which are of value. One is the right to be safe in one's person, liberty, property and freedom of expression within the bounds of law and of consideration for the rights of others. If this right is important, dictatorships of all varieties are intolerable. There are certain political rights which are of value. One of them, not generally recognized, is the right to have only qualified persons appointed to office or presented to the electorate as candidates for office. This is a very different thing from fetishistic democracy and all other forms of political romanticism. Political romanticism allows one to appoint officials and to vote for candidates regardless of qualifications, and the right to do this is a highly cherished right of fetishistic democracy. In religion one must have the right to go to hell if one does not wish to go to heaven, but that is a personal matter. No such option should be tolerated in government. In the field of politics we can maintain our personal rights only by maintaining the community rights, and it is a violation of the community rights to permit unqualified persons to govern.

Hence we may say that our Washington representatives of unromantic government have been deprived of nothing of value in not being allowed to vote for Tweedledee instead of Tweedledum, or for a second-rate orator instead of a third-rate orator, or for any of the other

offerings of political romanticism. However, they have been deprived of the right to have only competent persons appointed or presented to the electorate, and this is a serious matter, as it exposes them and the majority of our citizens, if not all of us, to the stupidities and iniquities of incompetent romanticism.

For a couple of years, we of the bureaucracy have been under fire from the romantic politicos and the business magnificos. Having discussed the politicos, I speak briefly of the magnificos. The lack of qualified persons in business is quite as impressive as in politics, and the magnifico is as much of a romantic as the politico. For thousands of years the only essential for engaging in business has been to have the necessary capital or be able to get it, and the principal qualification of the business man has been his ability to buy for one dollar and sell for two dollars. It is only too evident that one can be a banker without knowing the elements of banking, can engage in transportation without knowing anything about transportation, can own and operate drug factories and drug stores without knowing strychnine from Seidlitz powders, and can simultaneously be a banker and a bank wrecker, a railroad magnate and a railroad wrecker, the owner of a chain of stores and a dealer in poisoned products. This right to engage in business ignorantly and dangerously, and become unlimitedly rich at it, seems to be the essence of rugged individualism.

The proposals of the politicos for ending the depression, by and large, have been exceeded in vacuousness and inanity by the proposals of the business men. We demand certain qualifications of physicians before we let them practise, and we even require that plumbers know something about plumbing, but we risk our lives on many things we buy and never ask that the man who takes our money establish any qualifications for his business before he is permitted to engage in it. This romantic confidence in the business man has been justified in some individual cases, but too often it has been a prolific scurce of robbery, poisoning, homicide and other high crimes and misdemeanors. That it is not a more prolific cause of these things is due largely to the functioning of the unromantic government.

I said the business magnifico is a romantic. He is. He still carries with him his childhood patterns of behavior in his belief that much money is a good thing, and that wealth and power are roads to happiness, in spite of the fact that innumerable rich men have testified and their careers have demonstrated that the road to happiness assuredly does not lie in the domain of Midas or Caesar.

And since we are dealing with romantic government, what do we mean by romantic? According to the dictionary, romantic is relating to romance; fanciful; visionary; fictitious and improbable; fantastic; sentimental. Romance is prose fiction, an extravagant story, things strange, fascinating, heroic, adventurous or mysterious. These things are the essence of romantic politics—the spells of the spellbinder, the painfully concocted ambiguities of political platforms, the campaign promises, the sentimental misuse of the Washington, Jefferson and Hamilton traditions, the mysterious misdeeds of opposing parties and candidates and the rest of the propaganda regarding our fictitious virtues and our opponent's improbable vices.

As regards things fanciful, visionary, fictitious and heroic in politics, the writer has this thought in common with Stalin, Mussolini, Kemal Pasha and Hitler, that political parties should be abolished. But where the dictators' solution is merely a change from the romantic plural to the romantic singular, from fanciful parties to one allegedly heroic party, the writer would go far-

ther and abolish all political parties, leaving only the professional force charged with the serious, commonplace business of government.

What is the prospect of our giving up our romantic government in favor of unromantic government? There is a fair prospect. The unromantic civil service and other merit systems are actually making headway, slowly but surely, against romantic government. The United States and Britain have sound civil service systems, extending in Britain up to under secretaries in the cabinet, and just stopping short of assistant secretaries in the United States. A few of our states have merit systems, some of them effective. A very few counties have merit systems. Among our cities, 445 have changed from the romantic mayor to the unromantic city manager, and 165 other cities have city managers of limited responsibility. Historians may find that the greatest advance of Franklin Roosevelt's administration was his employment of expert advisers in economics and sociology.

Even more striking is the growth of unromantic government in the U. S. S. R. The romanticism of sovietism and dictatorship has held the attention of the world, but the really startling development is the rapid, sound and extensive establishment of unromantic and expert government in that country. Starting out with a drive against the professional groups, the Soviets soon revised their attitude and began to seek out and to develop experts. At present the high positions in engineering are held by engineers, and farming is under the control of agricultural experts. In my own field, veterinary parasitology, the United States has held the commanding position for years in the size of its Federal scientific staff and the extent of its effective measures for the control of parasites of animals, and imperial Russia was without competing personnel in this field. Within ten years the U. S. S. R. has moved to first place in size of scientific staff, far exceeding that of other countries, is putting out an unusual amount of good work and is beginning to forge ahead in its extent of control. In the field of unromantic government the U. S. S. R. promises to excel all other nations so greatly that the only competition will be for second place. If unromantic government is as superior to romantic government as I believe it is, here is the point at which the U. S. S. R. promises to educate the world on the subject of government. It seems entirely probable that the U. S. S. R. may be the first country to supplant romantic, political, non-professional government by non-romantic, non-political, professional government.

Romantic government has a strong hold on a humanity that reluctantly ceases to play with its toys. Mankind does not quickly give up its torch-light processions, its love of royal pageantry, its affection for the catchwords of democracy or autocracy, its belief in the magic of politicians, its desire for leaders to find the way to happiness along some road that does not involve thinking or hard work. But in time it does give them up. The torch-light processions are gone, in most countries the thrones have fallen, and although we still play at romantic democracy, indulge in the ceremonials of the fascist salute or the adoration of the Hakenkreuz, and still manifest faith in political promises and leaders, we shall come, sooner or later, to a realization that accomplishment of our ends lies in the direction of sound thinking and hard work. We shall employ more trained thinkers and competent workers, not as adjuncts to romanticists temporarily in office, but as the real and permanent government. We shall in time abandon romantic government, as we have abandoned fire worship, witchcraft and medieval chivalry, in favor of unromantic government by qualified persons only.

HUMAN RECAPITULATION

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THE course of embryological development suggests, in broad outline, the ancestry of the individual. The tendency on the part of the individual organism to pass through ancestral evolutionary stages is called recapitulation. The individual rapidly climbs the tree of ascent, repeating in his development the stages through which his ancestors have passed. Several traits of unsophisticated prenatal development suggest brief adherence to ancestral type.

The early embryonic structure of man is as undifferentiated as the structure of the amoeba. Later the individual exhibits the bilateral symmetry that characterizes the vertebrates, but for some time is a non-vertebrate animal, little differentiated in structure, with no complexity of parts. After the appearance of the vertebral column, or of cartilaginous centers which will develop into the vertebral column, there is a further differentiation of parts. Gradually the prenatal structure takes on the characteristics of a vertebrate mammal. There develop the so-called gill-slits, which are interpreted as corresponding with the gill-slits in fishes. These appear not merely in man but in the embryonic stages of reptiles, birds and all mammals. One pair of them develops into the Eustachian tubes, so that later they actually do perform a function.

The so-called milk lines along the chest of the embryo suggest a record of a time when man's ancestors, or at least ancestresses, had more than the single pair of nipples which characterizes our contemporaries. During prenatal life the nipple is much higher than it is on the contemporary adult; though a comparably high nipple is found normally on adult apes and other Primates. In the wrist of the embryo there appears a carpal element known as the *os centrale;* this disappears before birth, but in some of the anthropoid apes (the orang and the gibbon) and in many of the lower vertebrates it persists through life. The young embryo has from 7 to 9 vertebrae in the caudal region, whereas adult man, tailless, has only 3, 4 or 5 coccygeal vertebrae. In a human embryo of 7.5 mm crown-rump length, the percentage of length of tail is 16 per cent. of this dimension, whereas in adult man the length of these vertebrae is only about 3.5 per cent. of this dimension (sitting-height). The orang-utan, however, has only 2 or 3 coccygeal vertebrae—less than the average in man.

In the fetus of the genus *Colobus* and in *Hapale jacclius*, a primitive South American marmoset, vibrissae develop on a hillock of the skin, where they receive a branch of the ulnar nerve, and hence are regarded as primitive touch organs. In man this hillock occurs, apparently in only a small percentage of cases, in an early period of prenatal development. The hillock contains no sinus hairs and disappears during the ninth week of fetal life. This rare and ephemeral carpal hillock has been interpreted as an atavistic structure in the human embryo. Its only known functions is to remind us that the trait probably was present in our remote Primate ancestors.

The position of the phrenic nerve, which innervates the diaphragm, is interpreted as a survival from early ancestral stages. This nerve, as in the fishes, rises high in the neck. In the fishes the gills and heart are close together, under

the mouth. "As the gills changed to lungs, and an airtight compartment was provided for them, they moved downward, the diaphragm preceding them. But, as a matter of the most exquisite interest, the nerve which innervates the diaphragm, the phrenic, still arises high in the neck, and, traversing the entire chest at great waste, is the string which shows us where the diaphragm was and its pathway of migration during the ages."[1] Similarly, the lanugo, the hairy coating over the foetus, is assumed to represent the appearance of remote Primate ancestors.

There is also a progressive rotation of the foot upon the leg. In the prenatal condition the surface of the foot turns inward. Gradually the foot rotates on the ankle, the plantar surface assuming a plane more nearly at right angles to the sagittal plane of the tibia, although at birth the feet still turn inward.

In the human embryo the upper limbs are relatively much longer than in the new-born, and they become relatively shorter in youth and adulthood. The arms of the gibbon, on the other hand, are relatively short in prenatal life, and increase in length with growth. In the prenatal period, the arms of the gibbon, in proportion to body length, are, in fact, not much longer than those of the human fetus in proportion to body length.

Even after birth there are suggestions of recapitulation. The child can not walk until it is several months old. It can, however, go on all fours, that is, be a quadruped, before it can walk on two feet, that is, be a biped. Moreover, in the early stages of its earthly career, it is practically a quadrumanous creature, for its toes and feet are almost as mobile as its fingers and hands. With its toes it can grasp objects with almost the facility with which it can grasp them in its hands. When it learns to walk, the toes are turned in and the child walks largely on the outside of the foot, much as does an anthropoid ape. This inability to walk on two feet is accompanied by a remarkable power of handgrasp. A child two hours old can maintain its weight by overhead handgrasp for about a half minute. At the age of six weeks it can maintain its weight for about two minutes, that is, as long as can the adult who has given no time to the acquisition of this art. In view of the fact that most animals are able at birth, or soon afterward, to walk, crawl, swim or fly, in the manner of progression characteristic of their species, the absence of the ability to walk on two feet, and the corresponding ability to maintain the weight of the body by overhead handgrasp, are very striking. The only explanation seems to be the inheritance of adaptations which are no longer of much use to man, but which were of use to remote ancestors. Man is so conservative of the old, and so tardy in adopting the new, that he requires more than a year of postnatal existence to acquire the upright posture; and when he has acquired it, it is, for a few years, a very uncertain posture.

Yet, though many of the developmental changes from embryo to adult are in keeping with the supposition that the individual recapitulates ancestral history, certainly many of the changes are not consonant with that supposition. For example, during early prenatal life the height of the head is approximately one half the total body length. The proportion of height of head and of size of head to size of body decreases throughout the prenatal period and through much of postnatal life, at least until adulthood. At birth the size of brain in terms of size of body is about three times its proportionate size in adult life. That is to say, through much of the period of prenatal and postnatal development man

[1] Logan Clendening, "The Human Body," 107–108.

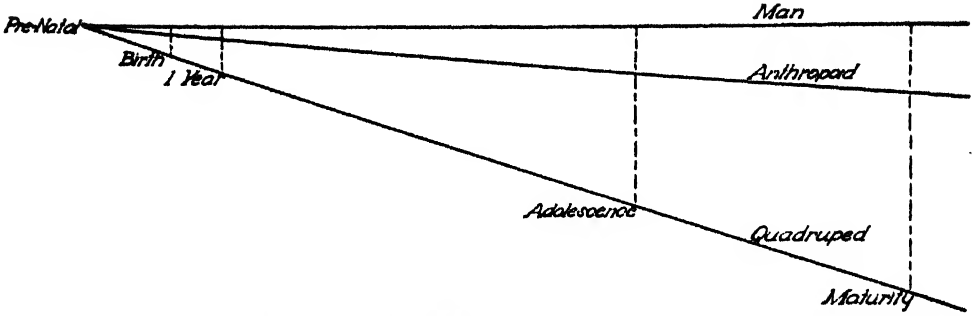
acquires less brain in terms of body size. This, of course, is contrary to the general story of evolution, which shows an increase in relative size of brain from the lower creatures to the higher, from non-Primates to Primates, and from most of the lower Primates to man.

Another fact often introduced to support recapitulation is the similarity in prenatal development between species assumed to be closely related, such, for example, as man and the anthropoid apes. That the close parallelism in development between most mammalian forms implies recapitulation must be doubted. Much of the similarity is the result of independent causes or, at least, would result from independent causes were there no common ancestry. Mammals start with similar structures—the (comparatively) undifferentiated germ plasm. They can develop only from undifferentiated structures to differentiated. In early prenatal development there will necessarily be considerable resemblance between man and ape, and even between man and quadruped.

Of necessity, too, with individual development the differences between the representative of one species and that of another will increase. Some of the similarities in early ontogenetic development, therefore, would be present if man and ape had evolved in different solar systems and had no common ancestry. Since man and ape have similar structures, it follows that the resemblances between them during embryological development will be greater than the resemblances between man and any other animal. They develop in similar prenatal environments, and their respective goals are not far apart; hence the paths which they traverse will diverge less than the paths traversed by man and any other animal. At birth they will be more alike than during adulthood, because the typical species characteristics do not develop until adulthood. In so far, then, as such resemblances are inevitable because of the circumstances of development, they must be regarded as similarities due to the operation of similar factors, rather than as due to common ancestral influences. The fact, for example, that people tend to eat at the same hour is due to the operation of individual causes, that is to say, to the responses of their individual organisms to circumstance, and not to ancestral influence. A similar observation applies to much of the evidence adduced in support of recapitulation.

A like observation applies to the argument that the procedure from simple to complex, from unspecialized to specialized, during embryological development, is the result of ancestral influence. It is true that the early stages of embryological development are comparable with early and primitive forms of life, and that the later stages of prenatal development show greater complexity of structure, as do later and higher geological forms; but the explanation of the resemblance probably lies in the logic of necessity. It is inconceivable that life should start in highly complex form. It is inconceivable, too, that the development of individual structure should start with a highly complex form. In either case, the procedure involves the necessity of passing from the less complex to the more complex, from the little differentiated to the more differentiated. Only those resemblances, therefore, which are not due to parallelism, or to the preconditions of development, imply ancestral influence. Resemblances which would exist even if there were no ancestral influence can not be interpreted as due to recapitulation. The "law of parsimony" applies here.

The matter can be illustrated by the accompanying figure. Development of man, anthropoid and quadruped starts in a similar undifferentiated plasm. The characteristics of the respective species



ILLUSTRATING THE NECESSARILY CLOSE RESEMBLANCE BETWEEN INDIVIDUALS OF ALLIED GENERA DURING EARLY ONTOGENETIC DEVELOPMENT.

appear gradually, and resemblances are necessarily greatest during early development. At birth the differences are greater, and at maturity they are most marked. Conversely, resemblances are greater at birth than in adulthood, more marked during later fetal development, and most pronounced in early embryological stages; and, almost of necessity, the resemblances between embryos are greatest in the case of species which are most closely related. If we apply the same logic to the anthropoid as to man—and we should extend that charity—the anthropoid recapitulates human ancestry; for the further back one traces anthropoid ontogenetic development, the more humanlike are the anthropoid characteristics. The logic which suggests that man recapitulates anthropoid ancestry suggests also that the anthropoid recapitulates human ancestry. At birth, and even in prenatal development, the human individual has certain so-called human characteristics in a larger measure than at maturity. This is notably the case with regard to size and shape of head, which is proportionally larger in prenatal stages and at birth than at maturity; at birth there is considerable cranial development and correspondingly little facial development. These changes in proportions run counter to the traditional implications of recapitulation. Since size and shape of head and the proportion between facial area and cranial area are considered important human characteristics, these traits of infancy can not be lightly passed over when weighing the recapitulation argument. Indeed, if one accepts recapitulation, much of the prenatal and early postnatal development implies that man's ancestry developed from a more human to a less human form, that is, from humanlike to anthropoid apelike, for in ontogenetic development the human individual acquires relatively less brain, proportionally greater supraorbital prominences and proportionally lower cranial vault. In relative head size in terms of trunk length, the *cebus apella,* one of the lower primates, exceeds man by about 8 units. The average diameter of the head

$$\left(\frac{\text{length} + \text{width} + \text{height}}{3}\right)$$

is in the human adult about 31 per cent. of trunk length. In the human newborn this percentage is about 57, while in the newborn gibbon and orang it is about 61. If these proportions are important in comparing man with ape, and contemporary man with prehistoric man, they deserve consideration when weighing the implications of recapitulation. Much of the postnatal development interpreted as implying recapitulation has, in fact, an easier and more obvious ex-

planation in the conditions inherent in development. The strong grasp of the newborn infant suggests inheritance from an arboreal ancestor, because it is greatly disproportionate to the infant's needs; but the approximately uniform curve of spinal column, anteriorly concave as in the ape, may be attributed to prenatal environment and posture. When the child ceases to go on all fours and walks erect the sigmoid curve develops, in response to the new need. The recapitulation theory is deductive rather than inductive, the *a priori* creation rather than the empirical finding of Müller and of Haeckel. Haeckel admits this, and indeed, boasts that the theory is *a priori*. The facts are forced into this scheme, the evidence is not judiciously weighed, and other interpretations are not considered. When Haeckel cited von Baer's position he deliberately suppressed the fourth conclusion of von Baer. This was: "Fundamentally the embryo of a higher animal form never resembles the adult of another animal form, but only its embryo." The reasons for that resemblance, at least sufficient reasons for it, have been indicated in the above paragraphs.

Thus, much of the resemblance between prenatal development in different genera is a sheer result of the laws of growth. Many of the "facts" of recapitulation, then, resolve into analogy and homology rather than into genetic relationship. The development of the embryo is determined not so much by its ancestral past as by the potentiality of the germ cells and by the goal common to its species. Its own organism determines its development—entelechy rather than ancestral influence—for a drive toward specific development is a potentiality of the embryo. Ontogenetic development in different genera is, therefore, determined by different specific causes. As it is not a common pervading hunger, but the independent demands of the respective organisms, which induce men to eat at about the same intervals daily, so no common ancestral influence drives embryological development along similar lines, but similar independent causes which operate in similar ways upon similar organisms with similar results. The recapitulationist sometimes confuses generic cause with specific independent causes which are similar and disregards the fact that the embryo as well as the adult has evolved.

A case in point is the gill-pouches (usually called gill-slits) which appear in the embryo of reptiles, birds and mammals. It is well to remember that "these structures resemble nothing so much as the gill-slits or gill-pouches which appear in the *embryonic* stages of fish. The gill-pouches of embryo reptiles, birds and mammals, do *not* resemble the gill-slits of the adult fish. Any one who can see can convince himself of the truth of this. All that can be said is that the fish preserves and elaborates its gill-slits, while the reptiles, birds and mammals do not preserve them as such, but convert them into other structures such as the Eustachian tube, the tonsils and the thymus glands. There is a similarity between the embryos of fish and of reptiles, birds and mammals, but the later stages of ontogeny have diverged. In the reptiles, birds and mammals, other adult stages have been substituted for the adult stage of the fish. During the phylogeny of the reptiles, birds and mammals, therefore, factors have arisen in the ontogenies which control the development from the embryonic stage onwards and which have produced progressive deviation."[2]

As Guldberg and Nansen remark, regarding the embryological development of the dolphin, "the embryo's development proceeds by the shortest road to its

[2] G. R. de Beer, "Embryology and Evolution," 47–48. Oxford, Clarendon Press, 1930.

goal. . . . The embryo seeks, by the most direct way . . . to attain to the special likeness of its parents, or to the specific form."[3] "It is the function of the embryo," remarks Shumway, "to become an adult without looking backward on ancestral history."[4] The embryo is, in large part, "a builder which lays one stone here, another there, each of which is placed with reference to future development."[5]

"If," to quote Gregory, "the biogenetic law were universally valid it would seem legitimate to infer that the adult common ancestor of man and apes was a peculiarly hermaphroditic animal, that it subsisted exclusively upon its mother's milk and that at an earlier phylogenetic period the adult ancestor was attached to its parent by an umbilical cord. The absurdity of this inference shows that the universal validity of the biogenetic law may not be taken for granted, and that in each instance the supposition that a given ontogenetic character is primitive requires independent evidence. If the biogenetic law were without exceptions, the marvelous processes of ontogenetic development would have only a historical or reminiscent aspect and not an anticipatory or adaptive one, since they would all be directed solely towards preserving a clear record of earlier adult states rather than towards the production of viable animals."[6]

In many respects man is tardy in developing the traits which distinguish the anthropoid apes; that is, he does not acquire until adolescence or adulthood some traits which are found in the anthropoid apes soon after birth or even during prenatal development.

Among these traits are the dentition, which is slower than in the ape; the prognathism, which is more marked in the human adult than in infancy; the hairy coat, which becomes more marked in man as growth proceeds; the pigmentation, which in man, especially in the dark races, increases after birth; the eyebrow ridges, which are not elevated in man until after adolescence; the projecting lower jaw, which becomes more prominent only after the permanent teeth have appeared; the spread of zygomatic arches, which increase with growth; the closure of the sutures of the skull, which is more delayed in man than in the ape. In his development, however, man becomes less like the ape in some respects, as notably in proportion of length of lower limbs to stature or to arm length, and more like the apes in certain other traits, as notably in those which have been listed above. If man recapitulates an apelike ancestry, he is, in general, rather tardy about it, and does not reach the end of the journey before old age overtakes him.

[3] Gustav Guldberg and Fridtjof Nansen, "On the Development and Structure of the Whale," pp. 23, 39. Bergen, Bergen's Museum, 1894.

[4] Waldo Shumway, "The Recapitulation Theory," *Quarterly Review of Biology*, 7: 98, 1932.

[5] F. R. Lillie, "The Embryology of the Unionidae," *Journal of Morphology*, 10, 1895.

[6] William K. Gregory, "The Biogenetic Law and the Skull Form of Primitive Man," *American Journal of Physical Anthropology*, 8: 375–376, 1925.

THE ROMANCE OF COMMON SALT

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NOTHING is said in the Bible concerning the addition of salt when Adam and Eve were created, although we know now that they could not have lived without it. Considering the scientific data relating to the appearance of life on the globe, especially the manner in which it was for ages maintained in the saline waters of the Paleozoic seas, we may mark the evolutionary evidence of the survival in man of this early ancestral element. In the earliest geological strata showing fossils, there are found only shells of sea animals and a few bones of fishes. These findings make it seem quite clear why there could be no life as we know it without salt.

In ancient times, salt was rare in inland countries and looked upon as a great delicacy. Governments frequently controlled the supply of salt. This has been notably true of China. The manufacture and garnering of salt was once the work of kings. Kingdoms went to war over the possession of salt deposits. There were some salt springs on the bank of the River Saale in Frankia over which two countries fought for fifty years, believing that such places are closer to heaven and prayers of mortals from thence more easily heard. Even in recent years, riots and bloodshed have occurred in Ecuador because of a salt famine resulting from damaged transportation. That salt had a deep religious significance to the ancients, there can be no doubt. Homer calls salt "divine" and Plato names it "a substance dear to the Gods." Moses admonished the children of Israel that "every oblation of thy meat offering shalt thou season with salt; neither shalt thou suffer the salt of the covenant of thy God to be lacking from thy meat offering; with all thine offerings thou shalt offer salt" (Lev. 2: 13). Salt had a symbolic significance by the Jews in the ritual of the covenant (Num. 18: 19). We can well imagine the consternation of the populace as Lot's wife was turned into a pillar of salt when she disobeyed her husband and looked back (Gen. 19: 26). Commentaries on the fate of this unfortunate woman recite the commonplace explanation that she was suffocated by a dashing spray of sulfurous salt which encrusted her whole body. In early America, the Hopi Indians gathered salt from a deposit in the Grand Canyon with great ceremony by making sacrifices to the Goddess of Salt and the God of War. The Zunis had a "salt mother" who was the genius of their sacred Salt Lake. There is a legend that the salt woman of the Acomas quarreled with the people and left their pueblos. On her way south, she stopped to rest at the present site of the Zuni Lake, where she was turned into the Salt Lake. The Acoma and Zuni Indians made long pilgrimages to gather salt. Of the Acomas, only the men of the Pumpkin and Parrot clans made the solemn journey to gather salt to be distributed to every home on their return. All the prehistoric Basket Makers of the Southwest, dating back to 2,000 B. C., made use of salt, and during the time of the Cliff Dwellers of Mesa Verde and elsewhere, it was pressed by hand into conical shapes, indicating that some ceremony may have been performed in which this product played a major part. Salt was habitually associated with offerings to the Gods by the Greeks, Romans and Semitic peoples. The Gods were worshipped as the beneficient givers of food and "bread and salt go together in common use and as a com-

mon phrase." Since covenants were made over a sacrificial meal, in which salt was a necessary element, "a covenant of salt" is readily understood.

Many expressions, having their origin in ancient times, have arisen because of the great religious and economic significance of salt. The preservative qualities of salt made it a symbol of enduring compact and, therefore, sealed an obligation to fidelity. Such expressions as "there is salt between us," "to eat salt in the palace" and "untrue to salt" were prevalent in ancient eastern countries. Even to-day North Africans and Arabs use the first saying as an expression of friendship. When Christ went up into the mountain he addressed his disciples by saying, "Ye are the salt of the earth," and he warned them that "if the salt has lost its savour, wherewith shall it be salted?" (Matt. 5: 13). Salt which has "lost its savour" is said to refer to an earthy residuum of an impure salt after the sodium chloride was washed out.

References to salt abound in the world's literature. A lecherous or lustful meaning is given the word when Iago refers to Othello "as salt as wolves in pride" (Othello III: 3). Shakespeare refers to salt in such other passages as, "Though we are justices and doctors and churchman, Master Pap, we have some salt of our youth in us" and "I have a salt and sorry rheum offends me" (Merry Wives of Windsor). Chaucer refers to "salt tears." Expressions such as "to pay a salt price," meaning costly or dear; "worth one's salt" or worthy of one's hire; "above or below the salt," indicating social position; "to salt," a plan of deception used in sprinkling mines with ore, or falsifying an invoice, are well known to-day. There was also once the dishonest practise of "salting" or sprinkling the roofs of houses with rock salt to entice the birds of the neighbors. "To salt away" or "salt down" means the preservation of meat, provisions or even money. B. Jonson writes that "his fashion is not to take knowledge of him that is beneath him in clothes. He never drinks below the salt." Such references to the social status of salt have evolved from an ancient custom of masters and servants dining in the same room with the master's table raised on a dais and adorned with a large and imposing salt cellar, while those of lesser social importance sat at tables supplied with salt receptacles to conform to their lower status in life. From this old custom has probably arisen the modern elevated speaker's table.

Salt has also played its rôle in the realm of superstition. It was early used in various rites for the exorcising of evil spirits. The spilling of salt in ancient times was an unlucky omen. In Leonardo da Vinci's famous painting of "The Lord's Supper," Judas Iscariot is indicated by the overturned salt cellar beside his right arm. Captured cities were sowed with salt as a symbol of perpetual desolation. Milan was once razed, burned, strewn with salt and plowed under by Emperor Frederick Barberossa. In Armenia, Russia and Greece, the newborn babies are sometimes rubbed with salt because of its supposed valuable properties in giving strength, vigor and endurance and in preventing corruption. In parts of Germany, salt placed behind the ears of a newborn or in a little package between the folds of the diaper brings sense and protects against evil spirits. In Portugal, after the birth of a baby, the mother and child are protected against evil influences by scattering ground salt on the roof of the dwelling so that the witches may keep busy gathering up the salt and do them no harm. In Flanders, women throw a package of salt behind them so that their confinement may have no evil consequences. In Ireland, salt is hidden in a baby's clothes to protect it against thieving fairies. In America, super-

stitious women throw a few grains of salt over the left shoulder, when any chances to be spilt, to avoid any kind of bad luck.

From the economic standpoint, salt has assumed vast proportions. Since earliest historical times, salt as an article of commerce has been of first importance. Marco Polo speaks of mountains of salt in Taican as follows: "The mountains that you see towards the South are all composed of salt. People from all the countries round, to some thirty days journey, come to fetch this salt which is the best in the world and is so hard that it can only be broken with iron picks. 'Tis in such abundance that it would supply the whole world to the end of time." Among the first roads built to facilitate trade were those to transport salt. The oldest road in Italy is called the Via Salaria or salt road. Salt mines in India have been in use since the time of Alexander the Great. Herodotus writes of the caravan routes to the salt oases of the Libyan Desert. Salt cakes have been used as money in Abyssinia and other parts of Africa and in Tibet. The Roman army was once given an allowance of salt for its officers and men. This salarium was later converted into an allowance of money for salt. From the term salarium comes our very significant word salary. Hence, without salt there could be no salary.

If your ancestors ate salt you are probably fair-skinned; if not you belong to the dark races. This rather astonishing hypothesis has evidently been advanced by some one interested in racial complexions. If you came out of the North, where there was plenty of salt, you are probably white; if from intermediate countries such as China, Korea and India, where salt was not so plentiful, you are probably moderately pigmented; if from the South, where salt was a rarity, you are probably black. The scientific proof of the relationship of racial salt intake to racial color may, in the minds of many, still be lacking, but the doubt does not mar the attraction of the theory.

The therapeutic use of salt has been common in medicine for many years. As a physiologic solution, having the same osmotic tension as the blood plasma, it has been administered intravenously, subcutaneously and by bowel as a standard method of reducing dehydration. It has been used in the treatment of hemorrhage and traumatic shock. In the above, the salt was added to water to make it isotonic and not for any known inherent value possessed by the sodium chloride in the treatment of disease. Only within recent years has therapeutic importance of salt been recognized by clinicians. It has long been known that sodium chloride is reduced in the body in lobar pneumonia, and in recent years it has been used in the treatment of this disease.[1] In 1912, Hartwell and Houget[2] found that they could prolong the life of animals with intestinal obstruction threefold by giving physiologic salt solution. The importance of the salt was not recognized by these authors, and their results were attributed to the relief of dehydration. The importance of salt in body water distribution was dramatically demonstrated by Rowntree[3] when he discovered that he could intoxicate animals and produce convulsions by excessive quantities of water introduced into the stomach. Such intoxications could be relieved or prevented by the use of salt solution. It has been noted that miners, working in high temperature, causing

[1] R. L. Haden, "Relation of Chloride Metabolism to Toxaemia of Lobar Pneumonia," *Jour. Lab. and Clin. Med.*, 10: 337, February, 1925.

[2] J. A. Hartwell and J. P. Houget, "Experimental Intestinal Obstruction in Dogs with Especial Reference to the Cause of Death and the Treatment by Large Amounts of Normal Saline Solution," *Jour. Am. Med. Ass.*, 59; 82, July 13, 1912.

[3] L. G. Rowntree, "Water Balance of Body," *Physiological Rev.*, 2: 116, 1922.

excessive perspiration, frequently have muscle cramps, which become very disabling. This disturbance can be completely relieved if the workmen drink a weak solution of salt water.[4] It is probable that the deprivation of chlorides lessens the gastric secretion and may interfere with digestion.[5] It is well known that a loss of all the gastric juice rapidly results in death.[6] Death can be delayed by administering water and sodium chloride. Persistent vomiting, resulting from experimental pyloric obstruction, will produce profound changes in the blood chemistry and frequently causes tetany.[7] This type of tetany is rapidly relieved by giving sodium chloride to replace the chlorides lost in the gastric juice. The great disturbance in water and chemical balance of the body is strikingly illustrated by the blood studies in acute pyloric, duodenal and small intestine obstructions.[8, 9] There is a marked reduction in chlorides and an increase in the non-protein and urea nitrogens and carbon dioxide combining power. These changes are apparently due to the loss of chlorides and other gastrointestinal juices incident to vomiting. That this is true is evidenced by the fact that the blood changes can be experimentally restored to normal by administering sodium chloride solution.[10] No other known substances will accomplish this restoration. Gamble and Ross[11] have aptly remarked that sodium chloride is the only one of a long list of salts containing both of the ions specifically required for plasma repair. Davidson[12] noted a decrease in the blood chlorides as a result of extensive burns. Other conditions in which a reduction of the blood chlorides has been found are acute peritonitis,[13] toxemia of pregnancy,[14] anaphylactic shock,[15] x-ray intoxication,[16] experimental high jejunostomy[17] and congenital pyloric stenosis.

Experimental work of Mitchell and Carman[18] points to sodium chloride as an important element in general metabolism. They found that rats and chicks grew and developed more rapidly on a

[4] E. M. Brockbank, "Miner's Cramps," *Brit. Med. Jour.*, 1: 65, January 12, 1929.

[5] R. K. S. Lin and T. G. Ni, "Changes in the Blood Constituents Accompanying Gastric Secretion," *Am. Jour. Physiol.*, 75: 475, 1925.

[6] L. R. Dragstedt and J. C. Ellis, "The Fatal Effect of Total Loss of Gastric Juice," *Am. Jour. Physiol.*, 93: 407, 1930.

[7] W. G. MacCallum, J. Lintz, H. N. Vermilye, T. H. Leggett and E. Boas, "Effect of Pyloric Obstruction in Relation to Gastric Tetany," *Bull. Johns Hopkins Hosp.*, 31: 1, 1920.

[8] R. L. Haden and T. G. Orr, "Chemical Changes in the Blood of the Dog after Pyloric Obstruction," *Jour. Exper. Med.*, 37: 377, March, 1923.

[9] R. L. Haden and T. G. Orr, "Chemical Changes in the Blood of the Dog after Intestinal Obstruction," *Jour. Exper. Med.*, 37: 365, June, 1925.

[10] R. L. Haden and T. G. Orr, "Obstruction of the Jejunum. The Effect of Sodium Chloride on the Chemical Changes in the Blood of the Dog," *Arch. Surg.*, 11: 859, December, 1925.

[11] J. L. Gamble and S. G. Ross, "The Factors in the Dehydration Following Pyloric Obstruction," *Jour. Clin. Investigation*, 1: 403, June, 1925.

[12] E. C. Davidson, "Sodium Chloride Metabolism in Cutaneous Burns and its Possible Significance for a Rational Therapy," *Arch. Surg.*, 13: 263, August, 1926.

[13] T. G. Orr and R. L. Haden, "Chemical Changes in the Blood of the Dog in Experimental Peritonitis," *Jour. Exper. Med.*, 46: 839, September, 1928.

[14] R. L. Haden and D. C. Guffey, "Case of Pernicious Vomiting of Pregnancy with Low Blood Chlorides and Marked Response to Sodium Chloride Therapy," *Am. Jour. Obst. and Gyneo.*, 8: 486, 1924.

[15] R. H. Major, "Studies of Blood Chemistry in Allergy," *Bull. Johns Hopkins Hosp.*, 34: 104, 1923.

[16] A. T. Cameron and J. C. McMillan, "Chloride Metabolism in Roentgen Ray Therapy," *Lancet*, 2: 365, 1924.

[17] T. G. Orr and R. L. Haden, "High Jejunostomy in Intestinal Obstruction," *Jour. Am. Med. Asn.*, 87: 632, August 28, 1926.

[18] H. H. Mitchell and G. G. Carman, "Does Addition of Sodium Chloride Increase Value of Corn Ration for Growing Animals?" *Jour. Biol. Chem.*, 68: 165, April, 1926.

ration of corn to which sodium chloride was added. Older clinicians[19] have reported that deprivation of salt is conducive to low fevers, gangrene of the lungs and intestinal worms. It is related that the ancient laws of Holland prescribed that criminals be kept on bread alone, unmixed with salt, as the severest punishment possible. The dreadful effect was beyond description. The criminals are said to have been devoured by worms engendered in their own stomachs. Salt is very irritating to the intestinal tract if taken by mouth in large quantities and may produce death. Salt was an old remedy for intermittent fever, dyspepsia, dysentery, for the expulsion of worms, application to fetid wounds, to stimulate the appetite and invigorate the system in scrofula, typhoid fever, granular inflammation of the eyes, emetic for poisoning, as a saturated solution rubbed on the chest for fainting and asphyxia, and to control hemoptysis and post-partum hemorrhage. The validity of some of these older claims for salt may, of course, be questioned, since its administration was entirely empirical therapy. That there is a germ of truth presented must be recognized.

There has in recent years developed a renewed interest in the metabolism of salt in the human body. Is its function to maintain proper osmotic pressures in the body; is it responsible in large measures for maintaining water balance; is it the source of the hydrochloric acid of the gastric juice; has it some protective action against certain types of toxemias; does it render the blood tissues more bactericidal; and does it play a rôle in the body growth? These questions naturally arise when a review of the studies of this compound are made. It is doubtful if its action can be fully explained on the basis of physical chemistry. Cushny[20] says that the sodium ion (Na) and the chloride ion (Cl) are both practically inert, except in so far as they change the osmotic pressure. He further states that they are necessary constituents of the body, but their action is limited to the alteration in physical properties of the fluids. Herrick[21] noted a reciprocal relationship between sodium chloride and glucose in the blood. If one of these crystalloids is added to the blood in excess the other promptly decreases, indicating that both function in maintaining osmotic balance. It is generally believed that the chloride ion of the gastric hydrochloric acid has its origin from sodium chloride. Dogs on a strictly salt-free diet will after a time secrete pepsin but no free hydrochloric acid in the stomach. By giving salt, the free hydrochloric acid is restored. Weed and McKibben[22] were able to demonstrate a decrease in the size of the brain by the intravenous injection of strongly hypertonic salt solution. Hughson and Scarff[23] were the first to demonstrate the effect of hypertonic salt solutions on peristalsis. They showed that a strong solution would immediately initiate active peristaltic movements. This work has since been verified and its clinical application demonstrated.[24,25]

The importance of sodium chloride as a therapeutic agent has been especially

[19] J. D. Palmer, "Sodium Chloride as a Remedial Agent," *Merck's Archives*, 5: 406, December, 1903.

[20] A. R. Cushny, "Pharmacology and Therapeutics," Saunders, Philadelphia, 1911.

[21] W. W. Herrick, "Reciprocal Relationship of Chlorides and Glucose in Blood," *Jour. Lab. and Clin. Med.*, 9: 458, 1924.

[22] L. H. Weed and P. S. McKibben, "Pressure Changes in Cerebro-spinal Fluid Following Intravenous Injection of Solutions of Various Concentrations," *Am. Jour. Physiol.*, 48: 512, May, 1919.

[23] W. Hughson and J. E. Scarff, "The Influence of Intravenous Sodium Chloride on Intestinal Absorption and Peristalsis," *Bull. Johns Hopkins Hosp.*, 35: 197, July, 1924.

[24] H. A. Carlson and O. H. Wangensteen, "Motor Activity of the Distal Bowel in Intestinal Obstruction," *Proc. Soc. Exp. Biol. and Med.*, 27: 676, 1930.

[25] T. G. Orr, P. N. Johnstone and R. L. Haden, "Use of Hypertonic Sodium Chloride Solutions to Stimulate Peristalsis," *Surg., Gynec. and Obst.*, 52: 941, May, 1931.

emphasized in the last few years. The restoration of salt balance by giving physiologic or hypertonic salt solutions in such conditions as intestinal obstruction, pyloric obstruction, peritonitis, duodenal fistula, abdominal distention, and in any condition in which excessive vomiting is a factor, is now recognized as life-saving therapy. The importance of sodium chloride in the treatment of extensive burns has been demonstrated by Davidson. The injection of a small dose of hypertonic salt solution for post-operative gas pains will often bring astonishing results.[26] When chloride is lost as a result of disease its restoration becomes a specific therapy for such disease. This is particularly true in obstructive lesions of the gastrointestinal tract.

Summary

Without sodium chloride there could be no life as we now know it. It has probably been an essential constituent of animal tissue since the beginning of life. Salt has played a very important rôle in the development of the human race from the standpoints of war, commerce, religion and superstition. Its importance in the therapy of many ills is now being recognized and its clinical application common knowledge in medicine. It is maintained in the body at a very constant level and is the most essential factor in controlling the water and chemical balance. The average adult body contains chlorine equivalent to about 300 grams of sodium chloride. It is found in all tissues but more abundantly in the skin, where it seems to be stored for ready use. Osmotic tension and acid-base equilibrium depend upon the salt balance. The average daily intake of salt with the food is 7 to 10 grams, but the adult requirement is only 2 to 3 grams. Normally the kidneys excrete the excess of salt, but in certain diseases of these organs excess of salt tends to increase and maintain oedema. Salt has also been charged with increasing blood pressure in arterial hypertension. For such conditions a reduction of the salt of the diet is indicated. Carl Von Noorden[27] warns that salt reduces the blood's ability to resist disease and points to the difference between the health of the sickly civilized man who uses too much salt and the robust savage who uses but little.

That there could never be a dearth of salt has been shown by some energetic mathematician, who has computed that the world supply is ample for its needs. If the entire ocean were dried up it would yield no less than four and one half million cubic miles of rock salt, or about fourteen and one half times the bulk of the entire continent of Europe above high-water mark.

To treat any disease by restoring to the body that which has been lost as a result of disease is the most rational type of therapy. Salt therapy is usually of this type. Withholding of salt, in certain diseases in which its retention seems too great, is just as rational as supplying a deficiency.

A knowledge of the disturbed metabolism of sodium chloride serves to stimulate our interest in other inorganic compounds of the body in general and forces a realization that such constituents may be of inestimable importance in the study and treatment of disease.

[26] T. G. Orr, "The Treatment of Postoperative Gas Pains," *Ann. Surg.*, 93: 144, July, 1931.

[27] C. Von Noorden, "Why Savages are Healthy," *Abst. in Popular Science Monthly*, p. 68, May, 1931.

SCIENCE SERVICE RADIO TALKS

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RECENT ARCHEOLOGICAL WORK IN THE UNITED STATES[1]

By FRANK M. SETZLER

ASSISTANT CURATOR, DIVISION OF ARCHEOLOGY, U. S. NATIONAL MUSEUM, SMITHSONIAN INSTITUTION

CONVINCING evidence has finally been produced as to the antiquity of man in the New World. A calendar, made up of the annual growth rings in pine trees, extending from the present back to 700 A.D., has enabled specialists to determine actual building dates for hundreds of ancient ruins in Colorado, New Mexico and Arizona. Additional and unsuspected data have been gathered concerning the tribes that inhabited Florida when Ponce de Leon discovered the peninsula in 1513. The mystery and misinformation with which the real American Indian has long been concealed have been measurably lessened. These are some of the important contributions made to the prehistory of our country in the past five years.

Archeology is the study of prehistory. Through archeology we seek to reconstruct living history; to lift the veil of speculation from those diverse peoples who, directly or indirectly, have contributed to our own civilization. Through archeology we endeavor to retrieve the history of peoples who left no written record of their own achievements.

The archeological approach, of course, must lend itself to the particular condition encountered. As Indian tribes differed in language so did they differ in material culture. When the Pilgrim Fathers landed on Plymouth Rock some of the Indians were still living in the Stone Age; some were farmers, dwelling in permanent villages whose very existence depended upon a highly perfected form of communal agriculture; some were hunters who followed the buffalo herds of the Great Plains. It is the story of these divergent Indian peoples, from their arrival in the New World down to the coming of European colonists, that the archeologist seeks to recover and record. Almost from its very beginning in 1846, the Smithsonian Institution has been concerned with this problem of aboriginal discovery and settlement. The earliest migrations of man to this continent; his dispersal and development into numerous Indian tribes; the conquest of his environment and his creation and cultivation of distinctive plants form but a part of the prehistory of the Americas.

Many theories exist in regard to the origin of the American Indian. The one most widely accepted at the present time is that our Indians all belong to the same parent stock, namely, the Mongoloid. This does not imply a direct relationship to the Mongols of the Gobi desert, nor to the Chinese or Japanese. It means merely that the preponderance of evidence points to a common ancestral stock for the American Indian and the Asiatic Mongoloids. The migration of these peoples from Asia across Bering Straits to Alaska, their dispersal throughout North and South America and their numerous distinct civilizations form the most fascinating chapters of American prehistory.

[1] Printed by the courtesy of the Smithsonian Institution.

Within the past five years certain excavations in New Mexico, at Folsom, and in the Guadalupe mountains; Gypsum Cave, Nevada; Nebraska and elsewhere on the western border of the Great Plains, have revealed a peculiar type of flint projectile point associated with the skeletal remains of certain species of animals now extinct in these regions. These biconcave flint points were found with two species of bison—*occidentalis* and *taylori*, the musk-ox, ground sloth and others. Such discoveries have naturally led to speculations among geologists, paleontologists and archeologists as to what geological period, or, if possible, what century before Christ these animals ceased to exist. Of course, all believe that these animals lived during the Pleistocene period, or Ice Age, but since this particular geological period covers many thousands of years, the exact date remains indefinite. The animals may have become obliterated toward the end of the Pleistocene, or at the beginning of the Recent Geological period. The evidence now in hand does not permit a finer time division. The finding, however, by Edgar B. Howard, working for the Philadelphia Academy of Sciences, of characteristic folsom points associated with the horns of a musk-ox in New Mexico would seem to indicate the former presence of a much colder climate than exists at the present time in the Guadalupe Mountains. Thus far no evidence of human skeletal material has been reported associated with these artifacts or the extinct animals. When such human skeletons are found together with these points, it will be of considerable interest to compare them with later Indian types.

To pass from the earliest human remains thus far discovered in North America to those most recently retrieved from the unmeasured past, let us review briefly the results of certain archeological projects recently concluded by the Smithsonian Institution. As aid to the government's Civil Works Administration program to relieve the unemployment situation last winter, the Smithsonian was invited to furnish trained archeologists to supervise archeological excavations in Florida, Georgia, North Carolina, Tennessee and California. This program, one of the most extensive ever attempted at one time in the United States, has resulted in the reconstruction of prehistoric Indian cultures beyond the expectation of American anthropologists.

In Florida, under the direction of M. W. Stirling, chief of the Bureau of American Ethnology, three important sites were excavated. Near Bradenton, on the west coast, a mound revealed the entire floor plan of a temple, giving the first outlines of such a Florida structure. It may have been at such a building that Juan Ortiz was used as a watchman, during his captivity among the Calusa Indians. Ortiz was the Spaniard discovered by De Soto when he landed at Tampa Bay, May 30, 1539. This is the first mound discovered in Florida which contained systematic cremations. In one corner of the temple a double row of posts reenforced the building where the cremations of the bodies took place.

Mounds near Cocoa-Rockledge, on the east coast of Florida, contained bodies of the Surruque Indians, who occupied this part of Florida when it was discovered by the Spaniards. Menendez, the founder of St. Augustine, held a council in 1566 at or near Cape Canaveral which was attended by no less than 1,500 of these Indians. The only knowledge of the Surruque left us by the early explorers of Florida is a brief catalog of repeated disasters, ending with their final extermination slightly more than 100 years after their first contact with Europeans. It was the purpose of the 1934 excavations to supplement these scanty historical records.

A third site, near Belle Glade, Florida, revealed exceptional data requiring

a great deal of further study before any conclusion can be reached regarding the possible relationship of the historic Indians with the ancient remains.

One of the most important sites examined in the Southeast was near the city of Macon, Georgia. Extensive excavations were made in a group of mounds overlooking the Ocmulgee River as well as in others within the city limits of Macon. One of the most interesting discoveries disclosed by the Macon party was a well-prepared clay floor of a circular building. This agrees in most particulars with early descriptions of the covered ceremonial house or "hot house" of the Creeks—such as served the Indians as a combination temple, state house and men's club house. By careful work the floor of this structure was entirely exposed. It consisted of a stiff red clay plaster packed and polished by numerous moccasined feet. In the center was a sunken fireplace and, at equal distances from this, post-holes which marked the former position of the principal roof supports. A most remarkable feature, and one never before observed in ceremonial houses of the southeastern Indians, is the encircling bench on which individual seats were modeled in clay and separated from one another by narrow ridges. Opposite the entrance was revealed the modeled head and body of a great bird, probably an eagle, raised somewhat to serve perhaps as a ceremonial platform. The decoration around the eye of this bird is similar to the conventionalized decoration used on pottery recovered from an old village site near Moundville, Alabama. This would seem to indicate a definite relationship between the Indians in these distant regions.

Near the present city of Murphy, North Carolina, a large mound was excavated which has been identified as marking the ancient town of *Guasili*, visited by Hernando De Soto in 1540. This site, at the junction of Peachtree Creek and the Hiwasee River, was described, at the time of De Soto's visit, as a town of 600 wooden houses—probably an exaggeration—and the capital of a province where the hungry explorers were given a hearty welcome and feasted upon dog meat. They caught and cooked some of the Indian dogs, to the amazement of the natives, who never ate these animals. The red men at once rounded up 300 of the creatures and gave them to the white men to cook. One of De Soto's men wrote: "The lord who bore the name of the province left the capital half a league to meet the Spaniards, accompanied by 500 of the principal persons of the country, very gayly dressed after their fashion. His lodge was upon a mound with a terrace round it, where six men could promenade abreast." This site or mound has been definitely located by Dr. John R. Swanton from its peculiar geographical location and checks with the description given by the early Spanish chroniclers as that of *Guasili*.

Within the Shiloh National Military Park, near Pittsburg Landing, Tennessee, several mounds and the adjacent village sites were excavated. The village site deposits revealed numerous house structures; large quantities of broken pottery vessels were found in the mounds associated with the burials. This famous Civil War battle ground will contribute largely to the reconstruction of the pre-historic Indians who used this beautiful site, located on the east bank of the Tennessee River, long before white men inhabited the region.

On the edge of Buena Vista Lake, eight miles southeast of Taft, California, is the long-abandoned Yokut Indian village of Tulamniu, which has not been occupied since the Spanish explorers visited the site in 1806. Since then the once populous aboriginal settlement has gradually been accumulating an ever-

increasing covering of vegetation and desert sand. It remained for the 200 Civil Works employees to record the history-telling relics of the village and probably solve some of the important questions concerning the aboriginal inhabitants and their mode of living. Various burial sites of the Yokut Indians were discovered. They were buried in a not particularly careful manner, but a stout post was placed beside each grave. The remnants of these posts may enable archeologists to establish a definite chronology for the region, thus turning prehistory into dated history for California. The cedar posts have the annual growth rings well preserved. It is hoped to learn, by comparing these rings with the long calendar of annual tree rings shown in the California redwood trees, the years when the grave posts were cut and placed as markers for the individual graves. By a similar calendar of tree rings recovered from numerous remains in the Southwest, an unbroken sequence from the sixth century A. D. to the present has been worked out.

Even though the material obtained from the ruins in the United States consists of non-perishable objects—except in dry caves and desert regions—the science of archeology has been able to develop certain techniques which will enable archeologists to determine definite criteria which can be used for establishing relationships between the Indian cultures in the various areas. Very little of the perishable material culture, such as wood, feathers, skins, cloth, etc., has been preserved, but by the excavation of historically known or documentary sites, we can obtain the essential archeological pages leading back into the dim or protohistoric period, and then on into the dark or prehistoric. Archeology, combined with the study of the skeletal material—physical anthropology—and the study of the living Indian groups—ethnology, hopes to reconstruct the unbiased history of the United States before Columbus.

HUNTING EARTHQUAKES

By Rev. JOSEPH LYNCH, S.J.
DIRECTOR, SEISMIC OBSERVATORY, FORDHAM UNIVERSITY

A LADY leaving a theater after a popular lecture on astronomy was overheard to exclaim to her companion, "But the most marvelous part of astronomy to my mind is how they were ever able to find out the names of all the stars." To many people it seems equally marvelous that at an earthquake observatory we are able to locate an earthquake almost as soon as it occurs. Yet in reality the location of an earthquake at an earthquake observatory is no more marvelous than the discovery of the name of a star by the one who gave it that name. The location of earthquakes at an observatory is like the water falling over Niagara—it can't be helped!

Some time ago, we read of the unfortunate sinking of the Nantucket Lightship by the White Star Liner *Olympic*. The *Olympic* was being guided to the lightship by radio waves. Nowadays, a ship can be quite definitely located by radio shore stations if she continuously sends out radio signals as the *Nantucket* was doing. In a similar way an earthquake can be located by earthquake observatories by the waves it sends out. The earthquake corresponds to the ship at sea constantly transmitting waves. The observatories correspond to the shore stations which pick up these waves and from their intensity and direction instantly locate the quake.

An earthquake is a sudden shifting of a part of the earth's crust. This shifting may take place near the surface or it may take place a hundred miles or more down in the crust. But wherever it takes place, it jars the nerves of mother earth and sends a quiver throughout her system as a blast in a stone quarry causes the ground in the neighborhood to quiver. This quivering of the earth might be likened to the quivers or ripples on the surface of a pond when a pebble has disturbed its waters. The quivers travel throughout the entire earth as the ripples travel over the entire surface of the pond.

How can these quivers be detected? They are too small to be seen and too feeble to be felt by the unaided senses. The seismograph is the instrument designed to detect and magnify these quivers. Its principle is very simple. If an ordinary playing card be balanced on the tip of the middle finger and a penny placed on top of the card, the card, without any practise, can be flicked away, leaving the penny on the finger. The card must be flicked quickly. The penny stays on the finger because of its inertia—a Latin name for laziness. It refuses to be hurried away as the card was and it stays there. When an automobile starts up suddenly, the passengers lurch backward because of their inertia—they refuse to be hurried and the car starts off momentarily without them so that they lurch backwards in the car. Actually, they stay still while the car moves from under them as the penny stays still while the card moves from under it. When the brakes of a car in motion are jammed on suddenly, the passengers lurch forward because of their inertia. In this case, they refuse to have their motion stopped so that when the car stops they continue forward. All bodies possess this inertia, and the heavier a body is the more inertia it possesses.

Inertia shows itself as a resistance to motion. If a body is at rest it wants to stay at rest. If a body is in motion, it wants to stay in motion. We hate to go to bed, but when we are there, we want to stay there. This is the principle of the seismograph—because of its inertia it stays still while the ground underneath it moves. A seismograph is a pendulum with its tip resting gently on the ground. When the ground underneath the pendulum quivers, as it does in an earthquake, the pendulum, because of its inertia, refuses to quiver so that if the ground moves slightly towards the right, the pendulum stays still and relative to the earth appears to move to the left. If the tip of the pendulum be resting in loose sand, the relative motion of pendulum and earth will be traced out in the sand. This was the arrangement in the early types of seismographs. An ordinary pendulum was suspended so as to have its tip resting in loose sand on the ground—the motion of the ground would then be traced out by the pendulum in the sand. As each new quiver was traced out, the figure on the ground became very complicated. To avoid this complication the next improvement was to have the tip of the pendulum resting not on the ground directly, but on a sheet of paper covered with lampblack. This paper was wound on a drum which was kept revolving by clockwork under the pendulum. With the ground at rest the tip of the pendulum would scratch out a white line in the lampblack on the paper as the drum moves continually forward under the pendulum. If the earth quivered, *i.e.*, if an earthquake occurred, the drum, since it is attached to the earth, would also quiver and this quiver would be traced out in the lampblack as a sideways motion due to the sideways motion of the drum under the tip of the pendulum. The pendulum is so suspended that it can only move from side to side in one

plane. If two such pendula be placed, one facing north and south and the other east and west, they will between them pick up any quiver from whatever direction it may come.

The motion of such a simple pendulum will, of course, be very slight—particularly if it is some distance from the scene of the quake. To magnify the motion so as to make it more visible, several devices have been introduced. In one instrument, the tip of the pendulum, instead of resting on the smoked paper directly, is attached to the short arm of a lever—the tip of the long arm resting on the smoked paper and acting as the pen. Other and better instruments do away with the smoked paper altogether and substitute for it sensitized photographic paper. The pen in this case is a tiny beam of light reflected from a mirror attached to the end of the pendulum—a motion of the mirror causing a motion of the beam of light over the photographic paper. This optical lever is a big improvement over the mechanical lever previously mentioned. The most sensitive types of seismographs have a coil attached to the end of the pendulum. Two powerful magnets are set up on either side of the coil and each quiver of the coil in this magnetic field generates a current which moves the mirror of a galvanometer, the mirror in turn reflecting a light spot back and forth across the photographic paper to give us our record of the earth's motion magnified about 2,000 times.

When an earthquake occurs, then the whole earth quivers and this quivering can be detected by seismographs, utilizing the principle of inertia. But how can we tell from a record of this quivering just where the earth did quake?

When the earth quakes, it sends throughout the earth two distinct kinds of quiver—two distinct kinds of ripples which travel at different rates. Just as in a thunder storm at each lightning discharge we both see the lightning and hear the thunder because both a light wave and a sound wave are sent out from the disturbance in the clouds, so in an earthquake two distinct kinds of waves are sent out—one pushing or compressing the earth ahead of it and hence called a compressional wave, and the other shaking the earth from side to side as it travels and hence called a transverse wave. Like the thunder and the lightning waves, these two earthquake waves travel at different rates—about five and three miles per second, respectively. For every second we can count between the thunder and lightning waves, the distance of the thunderbolt is one fifth of a mile from the observer, so for every second we can count between the compressional and transverse waves of an earthquake, the quake is a corresponding distance away—for instance, in the last Utah quake of March 12, the number of seconds counted at Fordham between the two quake waves was 293, amounting to a distance of 1,940 miles. The seismograph records the arrival of these waves, and the exact second at which each arrives is told by time marks placed automatically on the record by an accurate clock.

So much, then, for the distance of a quake from a given observatory, determined by the number of seconds elapsing between the arrival of the compressional and transverse earthquake waves. But how is the direction determined? If we have three stations in communication, the matter is simple. If we describe three circles on a globe with each of the three stations as centers and the distances of the quakes from the respective stations as radii, the three circles can only intersect at one point and that point is the center of the quake. With sufficient instruments we can locate the position of the quake from the records of a single station, but the description of such a method is beyond the scope of so short a talk.

In conclusion, just a word on the

practical side of earthquake study. One of the most important aims of seismology is the protection against earthquakes by proper building construction and proper and adequate insurance. Very careful study of the findings of seismology has been made by the Board of Fire Underwriters of the Pacific. A staff of qualified engineers has been maintained by them in the Los Angeles and San Francisco regions, studying the effects of earthquakes on buildings there, and their findings have resulted in considerable improvement in the building codes and in adequate insurance against earthquake loss. We always will have earthquakes, but they can be efficiently prepared for and adequately insured against at a reasonable cost, and the efforts of the Board of Underwriters of the Pacific in this connection deserve more than a word of thanks and praise.

HEALTH AND THE DEPRESSION

By G. ST. J. PERROTT

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One of America's greatest resources is the health and vitality of its people. Health outranks in importance our natural resources of coal and iron and forests. It is infinitely more precious than our gold and silver, our bank deposits or all the output of our factories. In the past, our energy and health made us the great nation that we are to-day. Has the health of the people of the country been damaged by the economic depression? Is sickness prevalent among the unemployed and their families? Are the sick receiving adequate medical care? Are the "depression poor" getting enough food and a balanced diet? Are we bringing up a crop of malnourished children to be the victims of tuberculosis in later years? These are fair questions, important questions—but we are only beginning to answer them. For while we gathered voluminous statistics on mineral reserves, bank deposits and factory production, we know little about the health of the people as a whole except what we could surmise from the number of persons dying each year.

When the economic depression reduced the standards of living of millions of Americans to a bare subsistence level, when many had inadequate food and clothing and shelter, and were forced to look to public charity for support, misgivings arose as to the effect of these conditions on health. But when the death rate was examined, it was found that fewer people were dying in these depressed times than had died during the preceding prosperity. Each year from 1929 to 1933, the deaths from all causes (including deaths of infants and deaths from tuberculosis) declined, until in 1933 the death rate had reached the lowest figure on record. This led optimists to speculate as to the possible advantages of the depression from a health standpoint. They talked of the desirability of "tightening the belt during hard times" and "living the simple life." Others felt that any ill effects of the depression would not be reflected immediately in an increased death rate, and furthermore that serious damage to the health of the people had been prevented by a very effective program of public health and social relief. Their chief concern was lest this relief work be discontinued before the economic emergency was over.

Surgeon-General Hugh S. Cumming, of the U. S. Public Health Service, recognized the need of obtaining additional

first-hand information on the health of unemployed workers and their families. So, early in 1933, he directed that a house-to-house health canvass be made in a number of large cities for the purpose of finding the nature and extent of illness in families of wage-earners that had been hard hit by the depression, and of comparing their health with that of more fortunate families where the wage-earner had kept his job throughout the depression. Districts were selected in the poorer sections of the cities but not in strictly slum areas. A record was obtained of the illnesses of each member of the family for the three months before the visit, together with the medical care received by any sick member of the household and whether it was paid for or obtained free. In addition, the income of each wage-earner was recorded for each year from 1929 to 1932. For a selected group of 1,200 families, information on the daily diet was obtained in order to judge if the food were adequate to maintain health. Physical examinations of school children in the surveyed families in two localities were made to determine the extent of malnutrition. During the course of the study, visits were made to the homes of some 12,000 families in ten cities by investigators from the Public Health Service and the Milbank Memorial Fund.

The incomes of these families show that their standard of living must have been very low. It was found that 75 per cent., or 9,000 families, had incomes of less than $1,200 in 1932, and 40 per cent. of them had incomes of less than $600 that year. In 1929, on the other hand, three fourths of these people had been in reasonably comfortable circumstances. On the day of the visit in 1933, one fifth of all the families were depending on public relief and many others had no means of support.

When the illness records of these people were studied, the highly significant fact was found that health had suffered most in families hardest hit by the depression. The illness rate was more than 60 per cent. higher in these families than it was among their more fortunate neighbors who had suffered no drop in income. Sickness among these "new poor" was more prevalent than among the "chronic poor" who had been poverty stricken even in 1929, a fact which suggests that ill health is in some way associated with sudden change in the standard of living. The direct effect of unemployment is suggested by the fact that the sickness rate in families having no employed workers was 66 per cent. higher than that in families with full-time workers and 27 per cent. higher than that of families with part-time workers only. These higher illness rates appeared among the children as well as among the adults. Malnutrition among children in families suffering the greatest drop in income was found to be nearly twice as high as in families in comfortable circumstances in 1933. Children in families without social relief were found to have a higher rate of malnutrition than similar families aided by relief.

The diets of these families reduced to poverty during the depression had suffered along with their incomes. Diets were particularly deficient in the protective foods—milk, citrus fruits and fresh vegetables. These foods were considered luxuries, and low-priced bulky and filling foods, such as beans and macaroni, were substituted. The deficiency in the diets of the new poor may well have contributed to their increased sickness.

The general conclusion from this survey of 12,000 families is that the highest incidence of disabling illness appeared in the group that suffered the greatest loss of income during the depression. This was true of each city separately as well as for the group as a whole. If these findings are representative of the country, why has not the gross death

rate increased? Why have infant and tuberculosis mortality, in general, continued to decline?

A final answer to these questions can not be given. Certainly the low death rate for the country as a whole is encouraging evidence that the economic depression has not killed very many of the American people. However, this indication should be accepted only in so far as it really is a sign of good health. The death rate is not an adequate criterion of the extent of sickness. It is not affected immediately by unfavorable living conditions unless starvation and pestilence are actually present. It does not promptly measure decreased resistance to disease. It is not an accurate measure, for example, of malnutrition. The human animal is hard to kill, and will take much punishment before actually dying. We now have a higher standard of health than one which is concerned merely with warding off death. The average American wants to be alive and well, not merely alive. If he is not well, he wants adequate medical care to make him well.

As we have seen, there are indications that while the average American is alive, he is not always as well as he should be. Sickness rates have apparently risen among the unemployed population, especially in those instances where social relief has been unequal to the situation. Signs of an increase in the number of cases of mental disease are not lacking. Malnutrition among school children has increased in some localities. Higher infant and tuberculosis mortality have been experienced in certain areas of New York City where unemployment was most serious. The urban death rate for the country has been on a higher level for the first six months of 1934 than for the corresponding period in 1933. Thus the health picture may not be as rosy as it has been painted.

Conditions would probably be much worse to-day were it not for the untiring efforts of the medical profession and public health and relief organizations. While the new poor in the surveyed families received considerably less doctor's care than that to which they had been accustomed in better times, the physicians of the country responded generously to the needs of these people. The doctor received no remuneration for over 50 per cent. of the visits made to this group. The hospitals also gave a tremendous amount of free care—85 per cent. of all hospital care to these families was free. This unselfish service, together with the care provided by public and private relief agencies, has probably prevented what might have been more serious results of the depression had illnesses gone entirely unattended.

While we can justly congratulate ourselves on past accomplishments, even more must be done in the future. The indication of increased illness among the unemployed may not indicate a serious condition now, but it does point a warning finger ahead. It must be recognized that, in addition to life, liberty and the pursuit of happiness, health is an inalienable right of the American people. Medical care is a necessity of life, as well as food, clothing and shelter. These necessities must be made available to all if the health and efficiency of the wage-earning population are to be maintained. We may not yet have felt the full effect of the depression on our health and vitality. Every effort must be made to preserve this great national resource.

THE GREATEST FACTORY IN THE WORLD

By Dr. GEORGE J. PEIRCE
PROFESSOR OF BOTANY, EMERITUS, STANFORD UNIVERSITY

PERHAPS I should justify at once the high-sounding title of this discourse, and I am glad to do so. Every pound of food, every particle of clothing, most of our houses, many of our implements, most of our luxuries, are the products of this factory. It has no subsidiaries, but it has units all over the world. Most of them operate only seasonally, some of them throughout the year; but their working day is as strictly limited as if by code or by union. The factory is the green leaves of plants.

If we undertake to state the total value of the food products alone we have to consider very large figures. The annual production of human food in the United States of America is valued at approximately fifteen billions of dollars ($15,000,000,000). The value of food produced for human consumption, but devoured before or after harvest by other animals, may be estimated at one quarter of this sum. The value of what might have become food for these predatory animals and for man, but consumed by parasites living on the food plants, may be estimated at one eighth of this sum. We may set the year's potential production of the United States at twenty billions of dollars worth of food. Because we can not appraise in dollars what nourishes the birds of the air, the beasts of the field, the wild animals of the woods and the creatures inhabiting the waters, we can form only a vague idea of the magnitude of the yearly yield. The quantity is stupendous, the value can not be stated in the terms of any currency. When we consider the secondary products, the cotton, wool, silk, of our clothing, the hides and skins in our shoes and gloves, the woods of our houses and furniture, the handles at least of many of our tools, the cases and cabinets of our pianos and radios, and add those values to that of the forests and jungles which are the homes of other men and of other animals, and from which we derive rubber, quinine and many other industrial and drug materials, we can imagine no measure of value. We may go back to an old expression, "Green plants stand between the animal world and starvation," but this gives us an idea of the importance, though not of the value, of the factory.

There is no general store of food in nature. In the earth's crust are accumulations of oil, coal, gas, iron, gold—the products of ages past. Here and there are bodies of fresh and of salt water. Man's need of materials for implements and fuel are supplied from these stores. But there is no accumulation of food, or of any raw material from which man knows how to make food. It is made annually, for the most part seasonally, in the hours between sunrise and sunset, whenever and wherever there are warmth enough and water enough. Because the production of food is periodic, with no considerable store anywhere, the world's margin of safety against starvation is at all times narrow. All concentrations of population into cities, towns, islands, ships, etc., involve the hazard of starvation, partial or complete. Under the conditions of our civilization the production and the consumption of foods may be widely separated, and in all cases most of the food made is consumed outside the factory.

The factory is the world of green about us, the green leaves of the fields,

the orchards and the gardens, the forests of the land, the seaweeds which clothe our rocky coasts and float in the oceans, those smaller weeds which infest our swimming pools and reservoirs, obstruct our irrigation ditches and may even constrict our streams and interfere with navigation. The leaves of land plants are ordinarily green in appearance. In autumn they may change to reds and yellows, in summer and in spring their greenness may be overlaid and obscured by red or yellow pigments, and parts may be blanched or empty, showing yellow or white. The seaweeds may be red or brown or green, but in every case green is the underlying color. Why this greenness? Just as furnace, engine, dynamo and motor are essential parts of any other factory, delivering the energy for operation, so the green color of plants delivers the energy required and used in the manufacture of food. This color is contained only in the living parts of plants. It is made by the living cells, it absorbs energy for the living cells, and this energy is used by the living cells in converting the raw materials into foods. The green color is a screen capturing energy. Like the photographic film or plate, the receiver of a telephone or the antenna of a radio, the green color of leaves intercepts and absorbs energy. The energy is used, applied and consumed in making foods from raw materials as coal is consumed in making cloth from fiber. The energy is sunlight. The quantity and quality of sunlight reaching the green leaves of plants varies with the length of day, the altitude, the exposure and the quality of the air. The dry clear air of the desert and the sparkling dustless air of the Sierra Nevada permit a larger fraction of total daylight, and especially a larger fraction of the violet and ultraviolet portions of the sunlight, to reach the surface than can pass through the high fog of our coast counties or the high humidity of the Atlantic seaboard. But of the sunlight falling upon the surface of a leaf only a part is absorbed, the rest being reflected or transmitted. If all the sunlight were absorbed leaves would look black. Only a part of the sunlight is absorbed and the rest escapes, giving us the impression of greenness. What is absorbed consists of radiant energy of certain wave-lengths, mainly red rays and blue rays. These rays are used to do the work of converting food materials into foods, raw materials into finished products.

The different shapes, sizes and positions of the leaves and other green parts of plants, in the sea and on the land, are primarily determined by the need of energy, the means of absorbing it; but protection against drying, protection against destruction by wind, rain and enemies, these also must be provided. The shape, size, texture, therefore, of every leaf represent the adjustment which the growing leaf made to all these influences, just as a boy grows to shape, size and color determined by his parentage and circumstances. The structure of the greatest factory in the world, the green parts of plants, is no less perfectly fitted for the intake of raw materials and the elimination of waste. Examination of the ground plan and elevation of such a factory discloses unnumbered green cells with air spaces between, forming a fairly compact palisade in the upper third and a loose sponge in the lower two thirds of the thickness of the ordinary horizontal leaf. Through the so-called breathing pores on the surface air passes freely, inward and outward, into and out of these air-spaces whenever the pores are open; and through a system of tubes, which also form the framework of the leaf, water moves from the roots and stems into the leaf and back again to stems and roots; water, carrying dissolved raw material, and dissolved foods, according to the direction of the current: intake and export, from air and soil to the factory,

from the factory to the growing or working or storing tissues, as the case may be.

The raw materials for this factory come from air and soil, the wastes return to air and soil, the finished products remain in the body of the plant. The raw materials are of three sorts, all very simple, all very stable, all very common and all readily dissolving in water. Some of them are solids—the soil substances; one is a liquid—namely, water; the third is a gas—the carbon dioxide of the air. This last is formed by human beings and almost all other living things, and given off to the air. It is formed when coal, wood, gas, gasoline, oil and many other substances are burned. Great quantities of it are formed in times of forest fire, and it escapes with other hot gases from the vents of active volcanoes. Nevertheless, although the quantity of carbon dioxide gas in the air is enormous, the dilution is strikingly great. Two hundredths of one per cent. is the usual proportion. Yet because it is a gas, and in gases which we call the air, it moves with such ease, freedom and speed that it is never exhausted in any one spot, no matter how rapid the absorption. It is unlike water in this respect, for water may be taken in or be needed by a plant faster than it can be provided. Hence frequent rain or irrigation is needed to maintain an adequate supply. And the solids are still slower. They move only in solution in the soil water or as they may be moved by washing. The solids, the plant foods, as the agriculturist calls them, or the food materials, as the botanist calls them, are the nitrates, phosphates, sulfates and chlorides which make up such a large part and the most valuable part of the soil. These furnish the nitrogen, sulfur, phosphorus, the iron, potassium, calcium and magnesium which are such important elements in our diet.

We have thus formed some idea of the factory in which all our food is manufactured—the green leaf; the energy with which it operates—the sunlight; the raw materials which it uses—carbon dioxide from the air, water from the soil, certain substances called salts which the soil water takes up, dissolves, from the soil.

Every day when it is warm enough and wet enough and light enough foods are made in green plants. These foods are sugars, starches, fats and oils and more complex substances called proteins. The first and simplest of these are sugars. All the rest are derived from them by subtraction or addition or rearrangement of atoms in the molecules. The combination of carbon dioxide and water into sugar is the most important chemical process in nature, for upon it depends the existence of the world of living things, of ourselves and of all the other animals and the plants. Applying energy which comes in the form of light from the sun to carbon dioxide and water, living cells manufacture in the hours of daylight the most valuable and one of the most common substances in nature. The process goes on daily. We see no smoke or dust, we hear no noise, we see and smell and taste no wastes from this factory. On the contrary, it purifies the air and returns to it one of its most valuable ingredients, oxygen.

How this combination is effected remains the business secret of the greatest factory in the world. In spite of the most careful, persistent and ingenious study of botanists, chemists and physiologists, the details of manufacture are unknown. The factory is known, the raw materials are known, and the energy; the products are priceless and indispensable; the process remains unknown.

In spite of this fundamental ignorance, botanists have enormously improved and increased the products; they have protected the factory from injury by parasites; they have protected

it from interference by soil and air pollutions, from poisonous gases, from the dusts thrown out by some of man's factories; they have made the production of food and its derivatives of all sorts more secure, more suitable for human needs, more abundant and cheaper. It remains for men in other fields to improve the means of distribution, so that each and all may have due share of the products of the greatest factory in the world.

DO SNAKES HAVE LEGS?

By Dr. BERT CUNNINGHAM
PROFESSOR OF BIOLOGY, DUKE UNIVERSITY

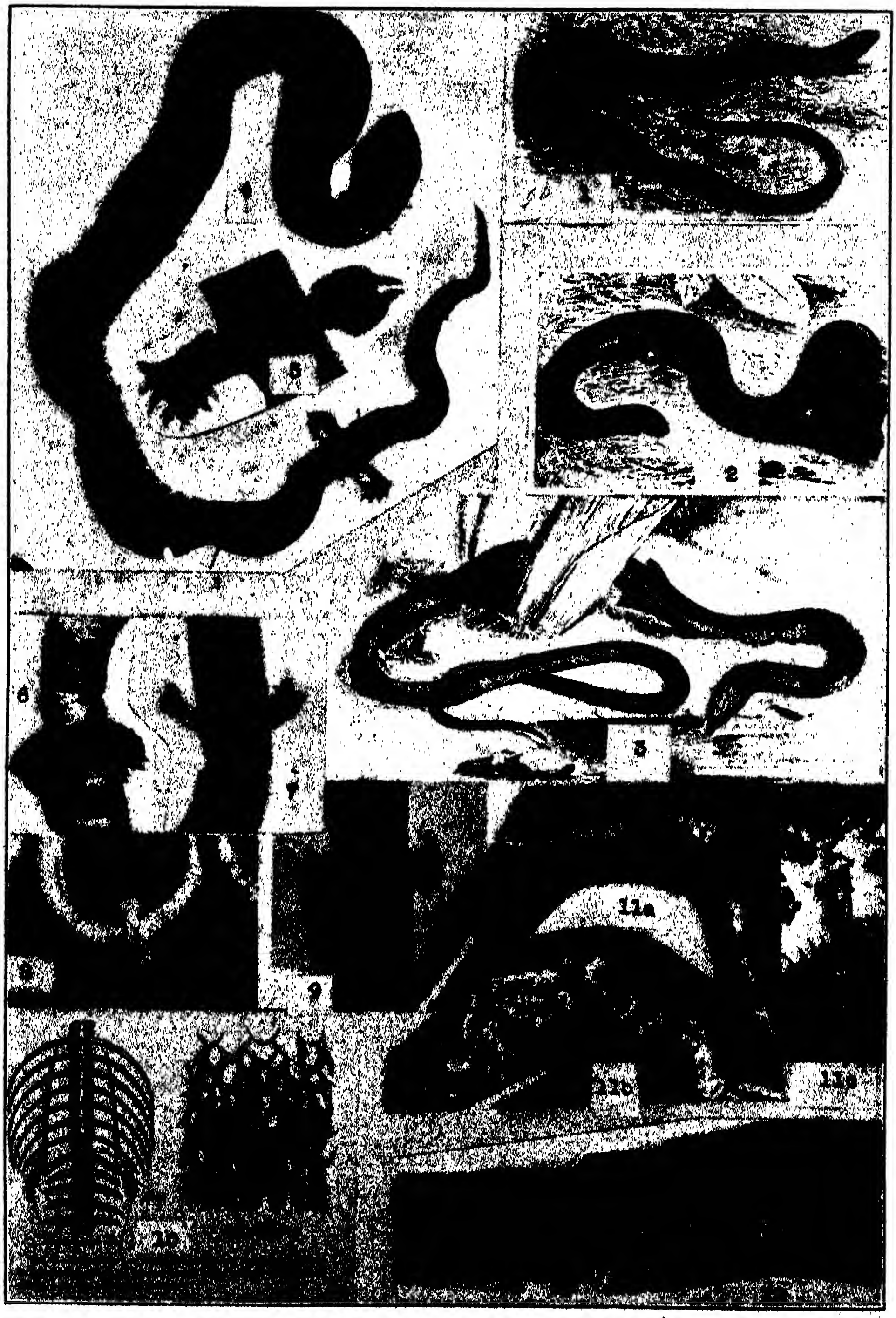
From time to time one hears of snakes that are said to have legs; in some of the cases the legs are visible under all circumstances, while in others they become visible only under some special circumstances, as for example when a snake is run over by an automobile or when a specimen is tossed into a fire.

It is commonly known that there are legless lizards that have bodies quite similar to snakes, so much so in fact that they are often mistaken for snakes. It is perhaps less well known that there are other lizards which have very small legs and exceedingly long snake-like bodies. Such a specimen is shown in Fig. 1. Doubtless upon superficial examination, one unacquainted with the technical differences between lizards and snakes might well call this a snake with legs. It has, however, several characteristics which separate it from serpents, namely, movable eyelids and external tympanic membranes which any one may easily observe; besides, there are certain internal structures, such as the shoulder girdles, which are never to be found in serpents, and the manner of hinging the jaw, which is entirely different from that of snakes.

In other snake-like lizards the posterior legs have disappeared and only small fore legs are present. This type is shown in Fig. 2. In still others the fore legs have disappeared and the hind legs have become flap-like (see Fig. 3) structures, bearing but little resemblance to legs. Still others have entirely lost both pairs of legs, and also have become so highly modified internally that it takes a herpetologist to separate them from snakes.

With such specimens as these possible and considering the superficial knowledge of the average person, one would not be at all surprised to hear reports of snakes with legs, the same being not snakes but lizards with slightly developed legs.

The explanation of the protrusion of legs when a serpent is crushed or thrown into the fire is as simple as the foregoing. For many years I have heard of snakes extending their legs when thrown in the fire, as well as under other circumstances. The story to the herpetologist is old and threadbare, but not so to the average citizen. For years I had hoped to examine at first hand one of these specimens. Finally the opportunity came. The case was reported in the newspapers, and I secured the specimen, a spreading adder. The animal with the distended "legs" is shown in Fig. 4. An x-ray of this specimen is shown in Fig. 5. At first glance the right and left structures are different, the right being more compact and appearing to have strips of bone within it. Figs. 6 and 7 show a similar condition observed in another species, while Figs. 8 and 9 show the condition in another specimen of the spreading adder, which was kindly loaned to me by the zoological museum of the University of Michigan. In none of these specimens is there a hint of any



bone structure similar to those of a leg, and in none of them is there any evidence of any bones similar to the pelvic girdle. This leads me to say what every herpetologist knows, that these structures so often called "legs" are but the copulatory organs (hemipenes) of the snake, which are extruded through the cloacal opening.

But the ancestors of snakes did have legs (be ye naturalist or fundamentalist), and there are some species still in existence which bear the marks of their ancestry. These have short spurs on the outside connected with bones running lengthwise of the body, such as are shown in Fig. 10. This condition is to be found in the python and some of its relatives.

It was our good fortune to be able to secure a specimen of *Constrictor orphius* from the West Indies, also loaned us by the University of Michigan, for photographic and x-ray purposes. A ventral view showing the spur is shown in Fig. 11, while Fig. 12, an x-ray, shows the internal relation of this structure to the long bones within the body. The spurs are thought to aid in climbing, and some look upon them as vestigial hind limbs.

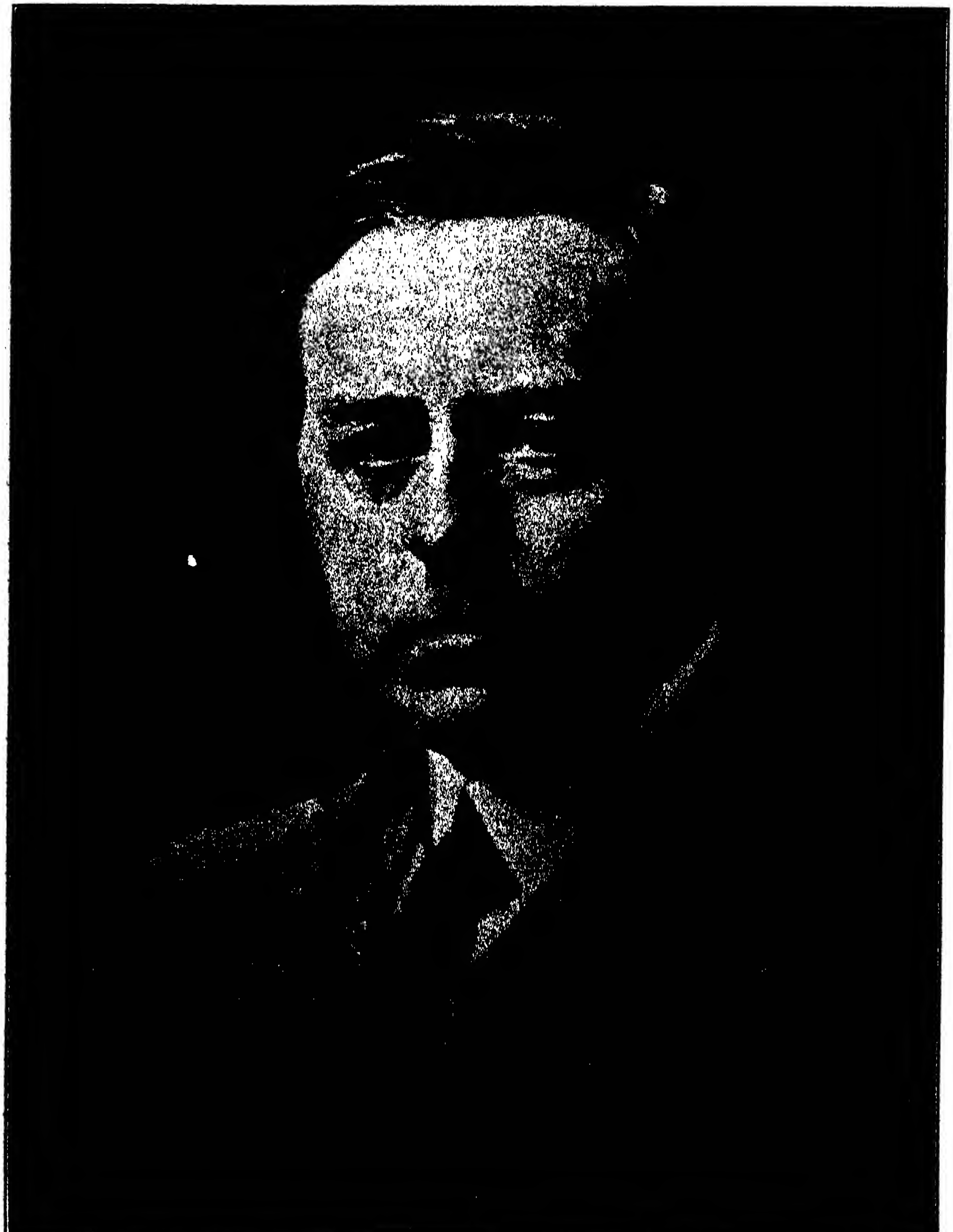
Since there are snakes with structures so nearly like "legs" and since it is assumed with good reason that the ancestors of snakes were legged animals, one should not be surprised if occasionally, perhaps extremely rarely, one should find a serpent with structures which, while anomalous, resemble legs. Such an instance was reported to the Société de Biologie in 1902 by Launoy.[1] Concerning the specimen he says: "At the level of the anus, laterally and symmetrically placed one may see two well-developed buds of unequal proportions and form. One is enlarged distally and attached to the body by a peduncle; the outer end is divided into two distinct digits which are without nails. There was no evidence of a pelvic girdle." Histological examination did not reveal any bony tissue in these structures. Whether these structures may be called legs or not, the author (Launoy) evidently thought they were and so expressed himself in the title of the paper.

When one is asked, therefore, if snakes have legs, the answer is that of the politician, "Well, sometimes yes and then again no," and again, "It depends upon your definition of snake and leg"; but if the question be restricted to our common North American snakes and to real legs the answer is most surely no—the structures so often thought to be legs are nothing more than hemipenes or copulatory organs. But that does not necessarily mean that no one shall ever find a snake with legs.

[1] "Embryon de vipère bipède et cyclocephale," *Comptes Rendus Soc. Biol.*, 54: 449–50.

"SNAKES" WITH "LEGS"

Fig. 1. A snake-like lizard, the three-toed seps, which has four very much reduced legs. Photographic copy, Harmsworth Natural History. Fig. 2. A snake-like lizard, the Mexican amphisbaena, in which the posterior legs have completely disappeared. Source same as above. Fig. 3. A snake-like lizard, scale-footed lizard, the fore legs of which have disappeared, and the hind limbs are scaly paddles. Source same as above. Fig. 4. Spreading adder, *Heterodon contortrix* (Linné) showing structures said to be "legs" in newspaper reports. Fig. 5. X-ray photograph of above specimen. Fig. 6. Ventral view of *Farancia abacura* Holbrook, showing protrusion of hemipenes. Fig. 7. X-ray photograph of above specimen—(specimen secured through the courtesy of the "Bug-House Laboratory"). Fig. 8. Another specimen of the spreading adder. Fig. 9. X-ray of the above specimen. Fig. 10. Photographic copy of python "spurs" and vestigial bones, from Romanes. Figs. 11, a, b, c. "Spurs" of snakes of the python type. Fig. 12. X-ray of *Constrictor orphius* showing the relation of vestigial bones and spurs. All x-rays were made through the courtesy of Dr. Reeves, of Duke University Hospital.



SIR JAMES JEANS

THE PROGRESS OF SCIENCE

THE BRITISH ASSOCIATION AT ABERDEEN

EARLY in September, for the third time during its one hundred and three years of existence, the British Association for the Advancement of Science convened in Aberdeen. On the occasion of its first visit three quarters of a century ago, His Royal Highness the Prince Consort was president of the association and delivered the inaugural address. To mark the occasion the following message was conveyed to the King:

Your Majesty,—We, the members of the British Association for the Advancement of Science assembled in the City of Aberdeen in annual session, desire humbly to recall to Your Majesty that it was in this City that His Royal Highness The Prince Consort assumed the Presidency of the Association in the year 1859. From the Presidential Chair, he conveyed to the assembled members of the Association a gracious message from Her Majesty Queen Victoria, and delivered an address which disclosed his own profound interest in the advancement of Science. The many marks of Royal favour which have been extended to our Association on subsequent occasions have provided further signal encouragement to us in our pursuit of the aims defined by His Royal Highness, and on all these counts we now desire to express to Your Majesty our humble gratitude.
J. H. JEANS, *President*.

The following reply was received from Sir Clive Wigram:

I am commanded by the King to thank the members of the British Association for the Advancement of Science for the loyal message which they have addressed to His Majesty, their patron, from the Inaugural General Meeting in the Ancient City of Aberdeen. His Majesty appreciates their kind remembrance of the occasion when the Prince Consort, as President of the Association, delivered a message from Queen Victoria to the members assembled in this City three quarters of a century ago. The King desires me to assure the members of his unabated interest in their meetings and his confidence that their investigations into the manifold problems confronting present day scientists will continue to be productive of results which will benefit mankind.

Over two thousand scientific men and women of Great Britain—together with workers of many countries—assembled under the presidency of Sir James H. Jeans in the Capital buildings of Aberdeen. Not for fifty years had the presidential chair been occupied by a theoretical physicist, and Sir James remarked that "in the interval the main edifice of science had grown almost beyond recognition, increasing in extent, dignity and beauty. Yet the theoretical physicist must admit his own department looks like nothing so much as a building which has been brought down in ruins by a succession of earthquake shocks," because it had been built on the "ever-shifting sands of conjecture."

Sir James continued his discourse on "The New World-Picture of Modern Physics" and in conclusion considered the topic of science and unemployment discussed in the April number of THE SCIENTIFIC MONTHLY by Drs. Millikan, Jewett, Coolidge and Karl T. Compton. It is thus of especial interest to note the last paragraphs of his address:

This last brings us to the thorny problem of economic depression and unemployment. No doubt a large part of this results from the war, national rivalries, tariff barriers and various causes which have nothing to do with science, but a residue must be traced to scientific research; this produces labor-saving devices which in times of depression are only too likely to be welcomed as wage-saving devices and to put men out of work. The scientific Robot in *Punch's* cartoon boasted that he could do the work of 100 men, but gave no answer to the question—"Who will find work for the displaced 99?" He might, I think, have answered—"The pure scientist, in part at least." For scientific research has two products of industrial importance—the labor-saving inventions which displace labor, and the more fun-

damental discoveries which originate as pure science, but may ultimately lead to new trades and new popular demands providing employment for vast armies of labor.

Both are rich gifts from science to the community. The labor-saving devices lead to emancipation from soul-destroying toil and routine work, to greater leisure and better opportunities for its enjoyment. The new inventions add to the comfort and pleasure, health and wealth of the community. If a perfect balance could be maintained between the two, there would be employment for all, with a continual increase in the comfort and dignity of life. But, as I see it, troubles are bound to arise if the balance is not maintained, and a steady flow of labor-saving devices with no accompanying steady flow of new industries to absorb the labor they displace, can not but lead to unemployment and chaos in the field of labor. At present we have a want of balance resulting in unemployment, so that our great need at the moment is for industry-making discoveries. Let us remember Faraday's electromagnetic induction, Maxwell's Hertzian waves and the Otto cycle—each of which has provided employment for millions of men. And, although it is an old story, let us also remember that the economic value of the work of one scientist alone, Edison, has been estimated at three thousand million pounds.

Unhappily, no amount of planning can arrange a perfect balance. For as the wind bloweth where it listeth, so no one can control the direction in which science will advance; the investigator in pure science does not know himself whether his researches will result in a mere labor-saving device or a new industry. He only knows that if all science were throttled down, neither would result; the community would become crystalized in its present state, with nothing to do but watch its population increase, and shiver as it waited for the famine, pestilence or war which must inevitably come to restore the balance between food and mouths, land and population.

Is it not better to press on in our efforts to secure more wealth and leisure and dignity of life for our own and future generations, even though we risk a glorious failure, rather than accept inglorious failure by perpetuating our present conditions, in which these advantages are the exception rather than the rule? Shall we not risk the fate of that over-ambitious scientist Icarus, rather than resign ourselves without an effort to the fate which has befallen the bees and ants? Such are the questions I would put to those who maintain that science is harmful to the race.

Sir James paid tribute to the late Sir William Hardy, owing to whose death he was in the presidential chair. The Hardy Memorial Lecture, delivered by Sir Frank Smith, constituted the first of the two customary evening discourses. He spoke on the preservation of meat, fish and fruit, a problem to which Hardy had devoted most of his life. The other discourse was given by Professor W. L. Bragg, who discussed "The Exploration of the Mineral World by X-rays."

Membership for the Aberdeen meeting reached a total of 2,784. The sectional meetings as well as the more general part of the program were unusually well attended, and it was agreed that the association had fulfilled the mandate laid down at the first meeting in York in 1831 to promote and direct the course of science, to foster intercourse among scientific men and to obtain more general attention for the objects of science from those not trained in science. The objects of the association were carried out in part by its extensive program of general and sectional excursions—features emphasized to a much greater extent at scientific gatherings abroad than in America.

THE DEDICATION OF THE LILLY RESEARCH LABORATORY

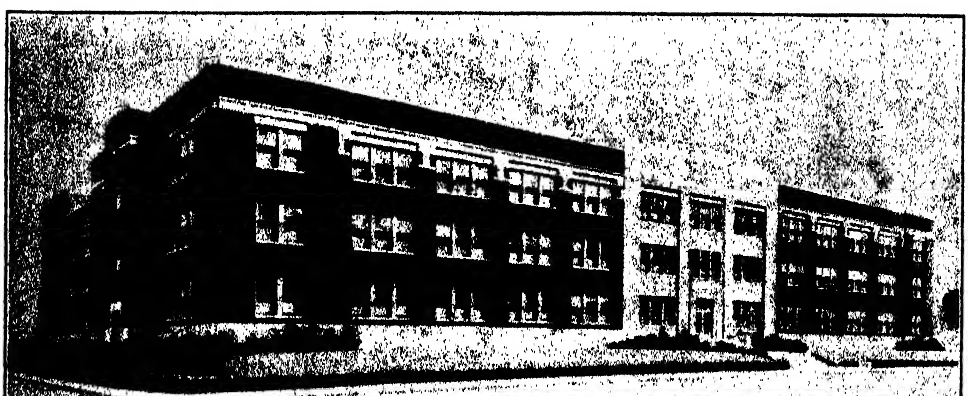
Pharmacy Week in 1934 will go on record for at least two notable occurrences, for it marks the week and the year when the American Institute of Pharmacy was dedicated at Washington, D. C., and the formal opening of the new Lilly Research Laboratories in Indianapolis on October 11. The exercises were attended by over a thousand guests, almost all of them in some way associated with research work. The gathering of distinguished visitors took place in a mammoth tent erected adjacent to the laboratories.

Eli Lilly, head of the Lilly organization, presided as chairman. Mr. J. K. Lilly, now chairman of the board of Eli Lilly and Company, responded briefly on "Research in Manufacturing Pharmacy." Mr. Lilly traced the progress of research in manufacturing from the time of his entrance into the organization with his father, who founded the Lilly organization in 1876, up to the present. Dr. Irving Langmuir, director of research for the General Electric Company, was the next speaker. He spoke on "The Unpredictable Results of Research."

The chairman then introduced Sir Frederick Banting, of the University of Toronto. Sir Frederick described "The Early History of Insulin."

Sir Henry Dale, director of the National Institute for Medical Research, London, and secretary of the Royal Society, was the last speaker on the program. He chose as his topic "Chemical Ideas in Medicine and Biology." Sir Henry spoke of the immediate objectives of research in such laboratories as those of Eli Lilly and Company, and of their natural and proper differences from those of the laboratories supported by academic or public endowment. It was his thought, however, that the differences in result for the progress of medical science are often more formal than real. He expressed the hope that the growth of cooperation between those working in these different spheres might yet bring to many the rather rare privilege that had come to him of migrating from one to the other and back again, and thus of knowing at first hand the best that each can offer.

According to Sir Henry, the change that has taken place in the scope of pharmacy has a revolutionary aspect. He cited the fact that not very many years ago it was predominately concerned with the traditional drugs that had come into use through empirical observation. Even though with the years had come additions, from time to time, the therapeutic outlook and attitude had changed but little for centuries. He pointed out that a beginning had been made by pharmacology toward rationalizing the use of those drugs in common use which had an action sufficiently definite to be susceptible to experimental analysis. The attitude of the physician and that of the investigator, in the opinion of the speaker, was, however, one of skeptical pessimism.



THE NEW LILLY RESEARCH LABORATORY AT INDIANAPOLIS

He did not suggest that palliative treatment no longer existed in medical practise or that its complete elimination was expected or even desirable. He cited the fact that alleviation of symptoms not only brings the richest reward of gratitude, but said that it might be the most urgent medical duty.

Sir Henry referred to the fact that he was speaking in the presence of Sir Frederick Banting and in the place where the large-scale production of insulin had its earliest organization, and that he felt he need not remind his audience of the revolutionary change which has taken place in the treatment of a disease that only a few short years ago was the despair of the physician.

Looking at the change as a whole one might distinguish two main contributory factors.

The first of these, in his opinion, was the recognition of infections as due to the invasion of the body by living microorganisms. He referred to the fact that it is a commonplace that preventive medicine was born of this discovery and that it gave a new direction to the therapeutics of infective diseases. He mentioned older remedies that owed their value to an unconscious application of such specific actions, for the control of infective organisms which modern research has since identified: cinchona, ipecac, mercury and the iodides. He contrasted these to the resources of modern therapeutics, with its range of antitoxins and bacterial products, its growing list of synthetic compounds discovered as a result of deliberate and organized research.

The second of these factors contributing to a change in outlook, according to Sir Henry, was the recognition of diseases due to the lack of substances normally present in the body. Modern therapeutics, in his opinion, can show no triumphs more brilliant than those which have followed the discovery of methods of preparing a number of glandular products in a state of sufficient purity to enable them, by artificial ad-

A PHARMACOLOGIC TESTING LABORATORY

WHERE THE STANDARDIZATION OF DIGITALIS, SQUILL, CONVALLARIA AND OTHER DRUGS OF SIMILAR NATURE IS DETERMINED. FROGS UNDER TREATMENT ARE PARTIALLY SUBMERGED IN CONSTANT-TEMPERATURE WATER BATHS IN SMALL INDIVIDUAL METAL BOXES SHOWN IN THE FOREGROUND.

ministration, to correct an abnormal deficiency.

He referred also to progress in the field represented by a second class of specifically acting substances, necessary like the hormones for healthy function and growth but obtained by the body mainly from food and known as vitamins.

Biochemistry, said Sir Henry, has long taken rank among the great divisions of science, while organic chemistry is showing a welcome tendency to recover its original objective, in studying the products and processes of living organisms.

The newer developments have but little relation to the art of the individual pharmacist whom our fathers knew, said the speaker, but we must resign ourselves as in other spheres of human activity to the loss of the individual art in exchange for scientifically organized production. In fact, he continued, in order to meet these novel, various and expanding demands of modern therapeutics, pharmacy has to become one of the most highly organized departments of scientific manufacture, covering an extraordinary range of expert knowledge and equipment. It now needs stables and pasturage, incubation rooms for large-scale culture of a wide variety of bacteria, and sterile rooms for manipulation of the products; chemical plant adapted to the difficult synthesis of complex and delicate compounds, or to the chemical and physical separation and purification of unstable natural principles, from animal organs only obtainable in adequate quantity and freshness by the cooperation of highly organized abattoirs. He cited, in addition, a much more fundamental requirement, calling particular attention to the need for research undertaken in the spirit of free inquiry, often with no immediate practical aim or any probable result other than the increase of fundamental knowledge.

The afternoon program was followed by an inspection of the new laboratories, the party being divided into small groups in the charge of guides. In the evening a banquet was tendered to the out-of-town guests. Mr. J. K. Lilly served as toastmaster and responses were made by Sir Henry Dale; Dr. Elliott P. Joslin, of Boston; Dr. George R. Minot, of Boston; Dr. Frank R. Lillie, of Chicago; Dr. George H. Whipple, of Rochester, N. Y.; Dr. Carl Voegtlin, of Washington, D. C., and Dr. G. H. A. Clowes, head of the Lilly Research Laboratories.

H. S. N.

SCIENCE AT THE CENTURY OF PROGRESS EXPOSITION IN 1934

A Century of Progress Exposition in 1934, as in the previous year, fulfilled its object of explaining the nature of the fundamental scientific discoveries of the past century and describing how they have been applied to the practical uses of men.

The Hall of Science, in which was portrayed the story of the contributions of science to mankind's advancement, was once more one of the most popular buildings in the exposition.

Again as in 1933 the main principles of mathematics, physics, chemistry, biology and geology were explained, with the purpose of making science a living thing to the layman. The progress of medical science and its contributions to human health and comfort were portrayed.

But important additions and improvements were made to the basic science exhibits to dramatize each phase so far as possible. Sound and light waves,

x-rays, liquid air, chemical processes, anatomy, geometric equations, disease prevention, physical phenomena, biological development and other phases were cleared of technical details and thereby were made more understandable to the lay visitor.

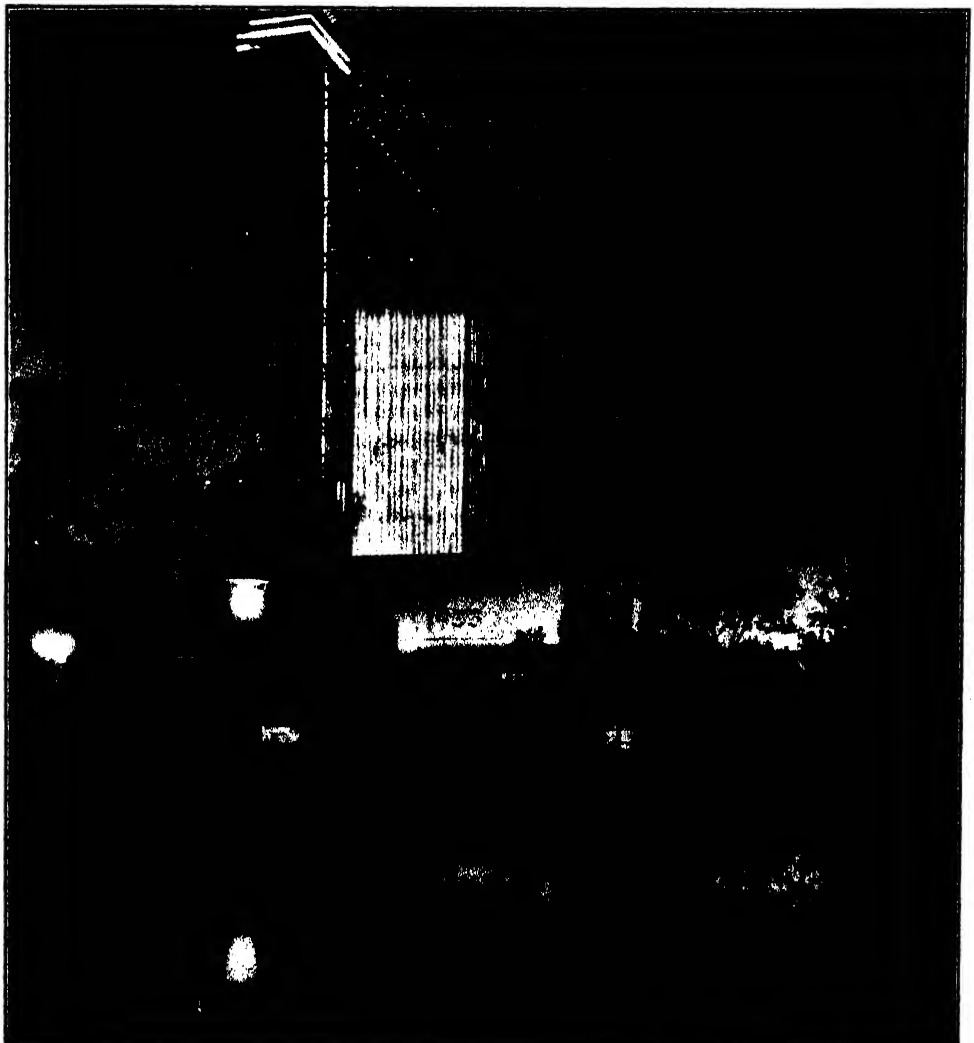
The exhibits in the Hall of Science gave even to the layman an increased appreciation of the fact that the different physical sciences are definitely interrelated and interdependent. Here was evidence that the basic sciences are dealing with different aspects of the same fundamental things. The sciences utilize each other's apparatus and conclusions and arrive by different routes at investigations of the same phenomena.

A perception of the correlation of all the sciences was given by eight exhibits in the Great Hall f the Hall of Science.

The Periodic Table of the Elements is an illuminated display of the ninety-two elements which constitute the earth and are the material with which all science works. The first periodic table of the elements was drawn up by the Russian chemist Mendeleeff in 1869. To-day all the ninety-two elements are known and have been fitted into their places in the series, chiefly by deliberate search along the lines indicated by the gaps in the original table.

Invisible radiation, the newest field of scientific work, is being studied by stratosphere balloon flights, which are exploring expeditions outside the living world. The gondola in which Auguste Piccard made the first stratosphere ascent in 1932 hangs above a skeleton frame like that of the sealed globe in which Lieutenant Commander T. G. W.

THE BUILDINGS AND GROUNDS OF A CENTURY OF PROGRESS



THE HALL OF SCIENCE WITH THE TOWER AND CABLES OF "SKY RIDE" IN THE FOREGROUND

Settle, U. S. N., and Major Chester L. Fordney, U. S. M. C., made their Century of Progress stratosphere ascension last year to a record height of 61,237 feet. In this framework the apparatus they carried for the study of the cosmic rays is to be seen. These are the most penetrating rays known. Our protection from them is our 50,000 feet of atmosphere, equal in protective power to two feet of solid lead.

The age and evolution of the earth were shown by the "Clock of the Ages," a giant dial representing the great eras of geologic time: Azoic, Archeozoic, Proterozoic, Paleozoic, Mesozoic and Cenozoic. As the revolving hand ticks off a second for each 10,000,000 years forty-two colored pictures are shown, representing the appearance of the earth and its inhabitants as the time advances. The time is almost run off before mam-

mals appear and man is on the scene in the last few seconds only.

A model of a molecule of common salt showed the structure of the atom. The smaller of the two spherical structures represented a positive ion of sodium, the larger a negative ion of chlorine. The number of white lights represented the number of electrons. The emptiness of the structure indicated the proportionate area occupied by the nuclei, of which, according to modern view, nearly all the mass of the atom is composed.

The gyroscopic compass, lent by the United States Navy, shows how this type of compass automatically aligns itself with the earth's axis and points true north and south, unlike the magnetic compass which does not indicate true north except in a few regions of the earth.

Conversion of electrical energy into mechanical energy is shown by an apparatus illustrating the operation of rotating magnetic fields.

The principle of cell growth is illustrated by a remarkable giant operating model of a basswood tree twig which "grows" from a three-year-old twig to a four-year-old twig in a few seconds by the multiplication of cells.

An interesting exhibit shows a sample of heavy water and the apparatus used to make it.

Thus around the Great Hall were arranged in series the exhibits of the basic sciences to show the definite accomplishments of science as they stand to-day and their application to the industries that supply the needs of civilization.

G. A. B.

DR. BERTHOLD LAUFER: AN APPRECIATION

Dr. Berthold Laufer, distinguished Orientalist, died suddenly on September 13, 1934. Dr. Laufer was born in Cologne, Germany, in 1874. After a course of general education at Cologne and Berlin he specialized in Oriental languages, receiving the Ph.D. at Leipzig in 1897. Coming to the United States in 1898, he became connected with the American Museum of Natural History, New York. This institution was then engaging in Asiatic researches. Laufer was given the leadership of the Jesup North Pacific Expedition to Saghalin Island and the Amur River region of eastern Asia for work on the ethnology of native tribes. He conducted the Jacob H. Schiff expedition to China for culture history investigations and collections, the material also coming to the American Museum. During his stay in New York he was lecturer on anthropology and East-Asiatic languages at Columbia University in Dr. Franz Boas's department. In 1908 he came to the Field Museum of Natural History, Chicago, and headed the Blackstone expedition to Tibet and China, meeting with success in obtaining great quantities of valuable material. The Captain Marshall Field expedition to China under Laufer's direction also produced notable scientific results. In 1915 Laufer became curator of anthropology in the Field Museum, a position which he held during the remainder of his life.

As a museum man Laufer ranked with the first in that science. The abundant and carefully collected material brought in by the various expeditions he directed was displayed in the best traditions of modern museum science. Viewing the Field Museum display of Asiatic art and technology it seems overwhelming that it could be the effort of one man. Laufer's knowledge and practise of museum science was displayed in all the branches of anthropology. He demonstrated

Keystone View Co.

BERTHOLD LAUFER

presentation of objects to the best advantage, with accurate labels and with all the accompaniments that would promote their value in teaching the public.

To scientific literature Laufer found time to make important contributions. On account of his thoroughness his writings will have a permanent value. He produced numerous books and over 200 monographs on ethnology, art, philology of Asia, histories of domestic animals and cultivated plants.

Among his general writings may be mentioned: "History of the Finger-Print System"; "The American Plant Migration"; "Tobacco and Its Uses in Africa"; "The Prehistory of Aviation"; "Geophagy." Important works on special subjects are: "Historical Jottings on Amber"; "The Diamond" (Chicago, 1915); "Notes on Turquoise in the East"; "Jade." Papers on the domestication of animals: "The Reindeer and Its Domestication"; "The Giraffe in History and Art"; "Insect Musicians and Cricket Champions of China"; "The Domestication of the Cormorant in China and Japan." Special monographs on linguistics and arts: "Dokumente der Indischen Kunst—Das Citralakshana nach dem Tibetischen Tanjur"; "Chinese Clay Figures"; "Prolegomena on the History of Defensive Armor"; "Chinese Grave-Sculptures of the Han Period"; "The Beginnings of Porcelain in China."

Dr. Laufer had by training as well as by natural ability a marked skill in acquiring languages, of which he had command of a respectable number. This

knowledge of languages stood him in good stead in the conduct of his expeditions to distant foreign countries. In Tibet, for example, there was required the native language as well as skilful diplomacy to collect cult objects from a hostile priesthood as well as to get them out of the country. Fortunately, Laufer had these qualifications in a marked degree.

In recognition of his attainments many honors were conferred on Dr. Laufer. He was collaborator of the U. S. Department of Agriculture, member of the National Research Council, member of the National Academy of Sciences, fellow of the Ethnological Society and of the American Anthropological Association, Oriental Society, Linguistic Society, Historical Science Society, Royal Asiatic Society, Shanghai, China; Royal Asiatic Society, London; Hakluyt Society; Société Asiatique de Paris; Société Linguistique de Paris; honorary member of the Archaeological Society of Finland; corresponding member, Finnish Society, Helsingfors; member, Society of Asiatic Art, the Hague.

Much of Dr. Laufer's energy was devoted to editorial work in the department of anthropology in the Field Museum. He was also editor of the Boas anniversary volume.

As the Asiatic study unveils more and more of its vast congeries of subjects for investigation, the loss of a man of the superior attainments of Laufer seems irreparable. What we have left after the animating spark is extinct is the monument of his brilliant work that will remain as a source and a mark for emulation by future scholars.

In character Laufer was gentle and kind, always willing to help in a worthy cause. He impressed one as a serious scholar. Those who knew him had frequent evidences that he was wise in the lore of the ancient world, coming out in pithy epigrammatic sayings, sometimes a stream of them. His literary style was nearly perfect. The leaflets written by Laufer for the Field Museum of Natural History are among the best in popular science literature.

WALTER HOUGH
U. S. NATIONAL MUSEUM

THE SCIENTIFIC MONTHLY

DECEMBER, 1934

THE ORIGIN, RISE AND DECLINE OF *HOMO SAPIENS*

By Professor WILLIAM KING GREGORY

COLUMBIA UNIVERSITY AND AMERICAN MUSEUM OF NATURAL HISTORY

HISTORICALLY the origin of man has been heavily beclouded by myths. Man makes himself the center of almost every cosmogony and the gods take sides for or against the tribal hero. This was true even among the Greeks, to say nothing of other primitive Aryans. The anthropocentric world of antiquity is typified by the Babylonian concept of the daily course of the sun, which returned each night to the east after traversing the subterranean land of the dead.

After a few flashes of Greek speculation on the origin of living creatures, Aristotle taught that men and animals have comparable parts and are generated in the same general way, and that man has an animal-like body inhabited by a divine soul. This dualism became orthodox throughout the Christian era and is held by the vast majority of civilized peoples even to-day.

The road to the Darwinian view of man's origin ran partly through the field of anatomy. The fact that pain often appears to be localized doubtless led physicians to study the internal organs, but such simple direct motives were perhaps conditioned and distorted by preconceived theories of the nature of disease. Astrology, always an anthropocentric philosophy, was then as now the enemy of an objective science of anatomy. It was not until many millennia of halting accumulations that, under the powerful solvent supplied by Darwin, the formerly isolated sciences of human anatomy, comparative anatomy, taxonomy, paleontology, geology and astronomy dissolved their own boundaries to form the science of anthropogeny, which deals with the origin of man.

Recently scientists have been going through another cycle of division, specialization and mutual recrimination which has greatly emboldened the enemies of Darwinian science and has enabled even astrology to win back multitudes to its fold. But the reexamination of our foundations which has been constantly going on leaves the science of anthropogeny, I believe, in a much stronger position than it was before, because it is supported by a vast and ever-growing accumulation of objectively established facts. Whatever may be the theories of mathematicians regarding infinitely large or infinitely small spaces and times, paleontologists have to do only with the ascertainable sequence of events in the one-way stream of earth history. These events, in so far as they deal with the origin and rise of the vertebrates, took place during a period of the order of magnitude of five hundred million years.

Man is a sort of living solar engine running by means of the potential en-

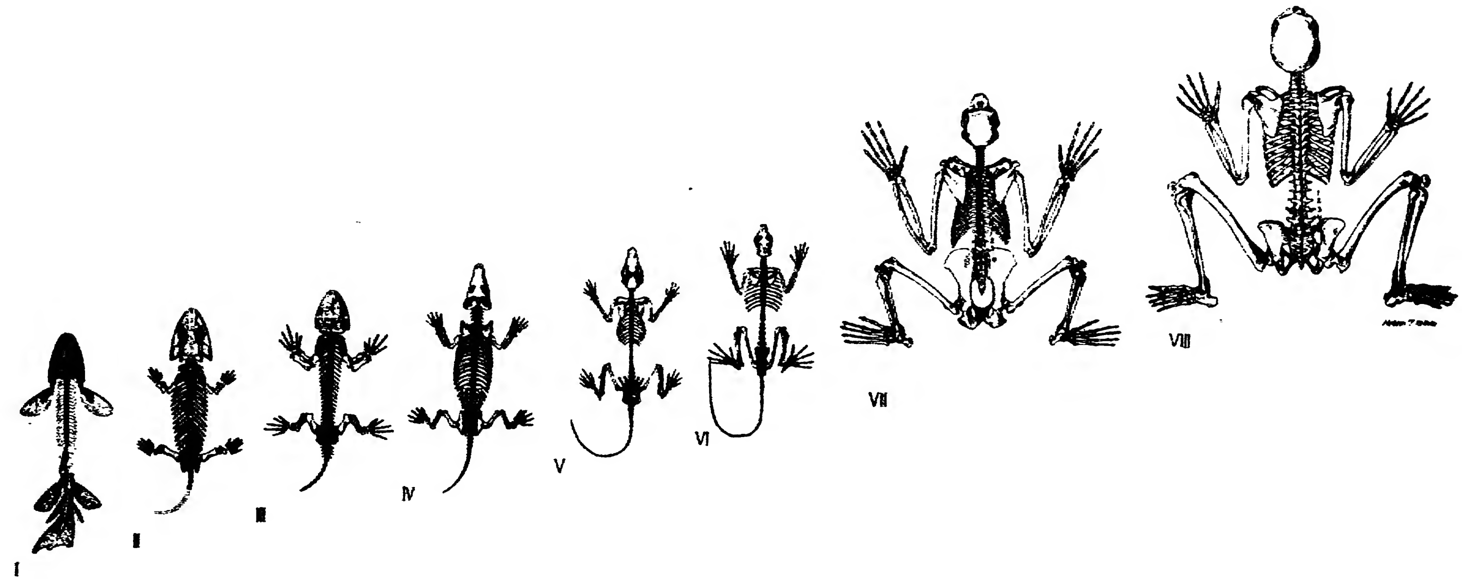


FIG. 1. MAN'S DEBT TO THE LOWER VERTEBRATES

SPECIMENS POSED IN PRIMITIVE TETRAPOD POSITION IN ORDER TO SHOW MAN'S INHERITANCE FROM THE LOWER VERTEBRATES OF EVERY BONE IN THE SKELETON.

I. DEVONIAN LOBE-FIN (*Eusthenopteron*).
II. CARBONIFEROUS AMPHIBIAN (*Microbrachium*).
III. PRIMITIVE PERMO-CARBONIFEROUS REPTILE (*Seymouria*).
IV. PROGRESSIVE TRIASSIC PRO-MAMMAL (*Cynognathus*).
V. PRIMITIVE MAMMAL (*Opossum*).
VI. PRIMITIVE LEMUROID EOCENE PRIMATE (*Notharctus*).
VII. TYPICAL ANTHROPOID (*Chimpanzee*).
VIII. MAN.

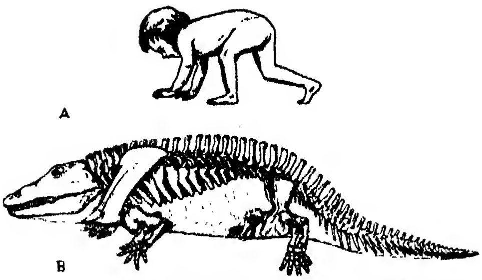


FIG. 2. COMPARISON OF PERMIAN AMPHIBIAN (*ERYOPS*) AND MODERN CHILD, RUNNING ON ALL FOURS

ergy that he has stolen from the plants and animals. This of course is nothing new, but for our present purpose it is fundamental. On the physical side man is primarily a machine for the transformation of potential into kinetic energy and on the biological side man is in a sense a parasite and a robber, sponging on the plants, killing the animals and eating them both. Moreover, as we shall presently see, man's ancestors have practically always been robbers, not until recently killers of big game but persistent harriers of creatures smaller than themselves. So that there is more than a kernel of truth in Bobby Burns's scornful lines:

> My ancient but ignoble blood
> Hath rolled through scoundrels ever since the
> Flood.

The first business of a robber after he has secured his booty is to get away with it before some other member of the profession comes up to demand a share. For that reason, among others, vertebrates are provided with a locomotor

FIG. 3. THE LOCOMOTOR APPARATUS OF A TYPICAL FISH (*ROCCUS LINEATUS*)

apparatus, including a backbone and pectoral and pelvic limbs. ***Homo sapiens*** is found in possession of this accessory to crime. He conceals it by strutting about on his hind legs and looking as dignified as possible, but this small child (Fig. 2), quite in the manner of small children, is giving away family secrets and his actions speak louder than words; for in running on all fours he reverts, so to speak, to the quadrupedal habit.

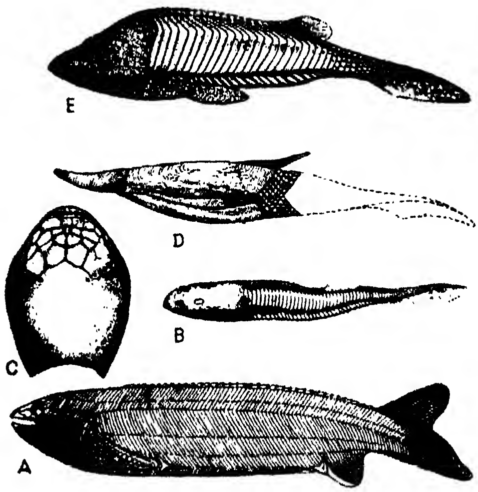


FIG. 4. SOME OF OUR EARLIEST KNOWN KINSFOLK

UPPER SILURIAN AND DEVONIAN OSTRACODERMS. A. *Pterolepis* (AFTER KIAER). B. *Trematąspis* (AFTER ROHON). C. *Tremataspis* (AFTER PATTEN). D. *Pteraspis* (AFTER POWRIE AND LANKESTER). E. *Cephalaspis* (COMPOSITE, MAINLY AFTER PATTEN).

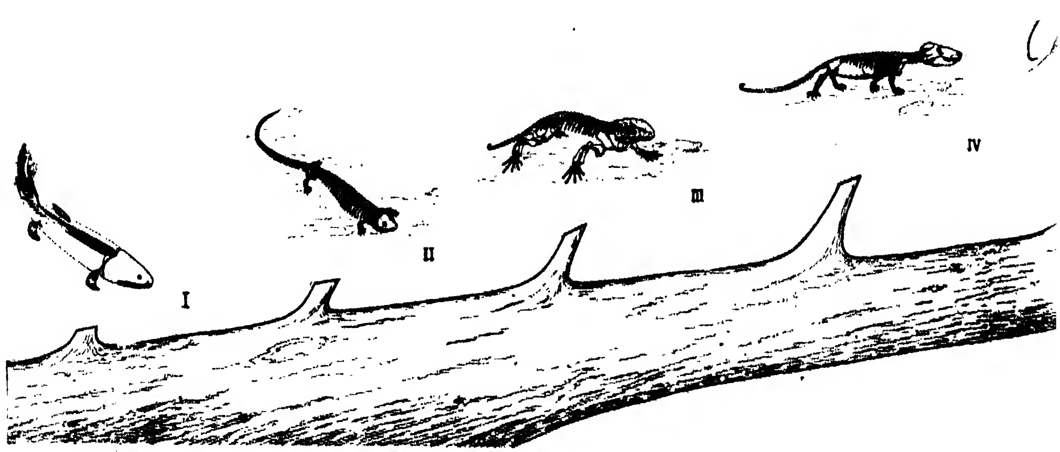
The locomotor system of *Homo sapiens,* like that of other vertebrates, **is distressingly complicated in its details, but what may be called its basic and chief subsequent patents are of a masterly directness and simplicity. A fish moves through the water, as we know, by bending its elastic body first to one side, then to the other, so that it waves like a flag. It is enabled to do this because of its serially arranged, contractile myomeres or W-shaped muscle**

flakes, which in contracting pull on the septa between them. Each myomere may be said to be the larger locomotor unit of the vertebrate body, and from these simple, serially arranged units the more complex axial and appendicular musculatures of the higher vertebrates have been derived. The smaller units of the locomotor apparatus are the single muscle cells, which have the basic property of contracting when stimulated by their nerve fibrils, thereby performing mechanical work. Exactly how they do this lies beyond my field, but the point is that in contracting the muscle cells use up some of the energy stored in the body and thus contribute to the endless round of getting, storing and spending energy which makes up the game of life.

In Fig. 1 our friend *Homo sapiens* is seen in the daily line-up, divested of his god-like exterior and forced to assume the suppliant posture of his humbler brethren. He is instantly distinguishable from them, however, by his swollen head. The five-and-ten system of prehensile organs, which is one of his most useful possessions, he has inherited from a long line of nefarious ancestors, and no other animal has been more successful in beating Mother Nature at her own game.

The earliest known forms of the vertebrates, namely, the ostracoderms of Silurian and Devonian times, were already in full possession of the basic vertebrate patents and were in these respects nearer to man than they were to their unknown invertebrate ancestors. However, they had not yet attained jaws of the shark type and probably fed on very small animals or organic particles.

From ostracoderm to man the gap is mediated by a procession of fossil and recent forms. Although none of these forms may lie in the direct line of ascent to man, they are the residue after the elimination of thousands of other vertebrates which were specialized in other directions; and all the forms of this residual line retained the five digits on each hand and foot which we must expect to find in all the ancestors of man down to the lobe-finned fishes that started the very useful business of having hands and feet. If space permitted I could review the evidence that hands and feet have been derived from paired fan-like paddles, and the latter in turn from keels and rudders formed from projections of the flattened lower surface of the body, which was roundly triangular in cross-section. In any case, when paired paddles had once been acquired they were, in the lines of the lobe-finned, air-breathing fishes, soon turned to a new use as limbs. These amphibious creatures then began that conquest of the dry land which was one of the great events in the history of man's forefathers.



At first the early four-footed ancestors of man had to deposit their eggs in the water, but eventually they learned, so to speak, to enclose the eggs in a shell and later to eliminate the shell and nourish the young within the body of the mother. By this time they had attained the grade of mammals and were able to run instead of crawl. About the time of the later dinosaurs the mammals began to climb up into the trees and the common opossum is a "living fossil" from this earliest tree-living stage of existence. But early in the Tertiary Period, or Age of Mammals, a certain branch of the mammals acquired a new mastery of the technique of rapid locomotion in the trees and we have the oldest known fossil Primates of the Eocene epoch. Going on to still more daring ways, certain primitive anthropoid apes learned the trick of brachiating, or swinging by the arms and leaping through the air. The modern gibbon is probably a somewhat over-specialized virtuoso in this art, but our own ances-

FIG. 5. STRUCTURAL SERIES OF SKELETONS FROM FISH TO MAN
I. Devonian lobe-fin (*Eusthenopteron*).
II. Carboniferous amphibian (*Eogyrinus*).
III. Primitive Permo-Carboniferous reptile (*Seymouria*).
IV. Progressive Triassic pro-mammal (*Cynognathus*).
V. Primitive mammal (*Opossum*).
VI. Primitive lemuroid Eocene primate (*Notharctus*).
VII. Proto-anthropoid (*Gibbon*).
VIII. Typical anthropoid (*Chimpanzee*).
IX. Man.

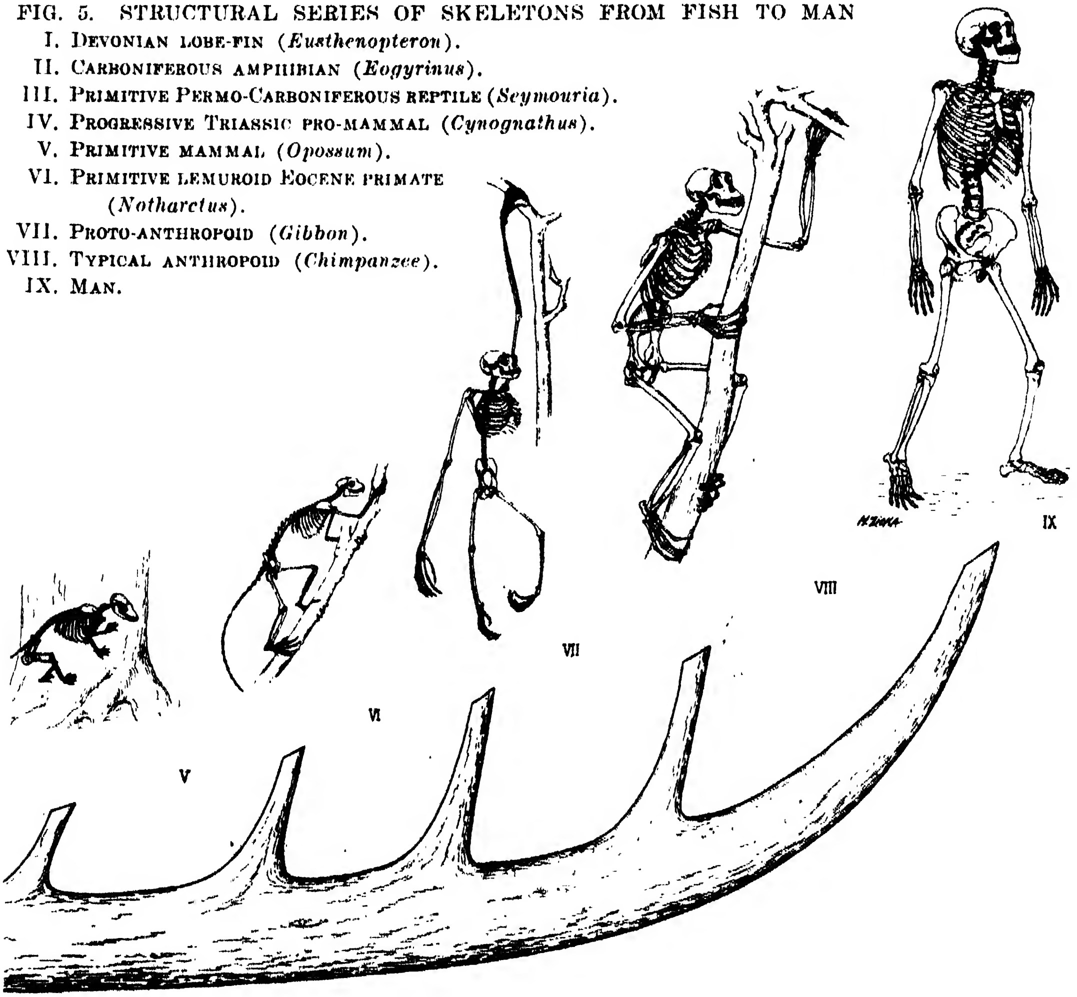


FIG. 6. SKELETON OF GIBBON FROM THE EAST INDIES

THE APE THAT SOLVED THE PROBLEM OF WALKING UPRIGHT.

tors must have learned at least the rudiments of it.

For reasons that can only be conjectured, some of the anthropoid apes then began to spend more and more time upon the ground. Finally some of their descendants found themselves out on the plains, with possibly the habit of rearing up to look over the grass tops. In any case, there is the most abundant and convincing anatomical evidence that man, who for perhaps a million years or more has walked erect, traces his ancestry back to arboreal apes with grasping feet. The important thing to note now, however, is that this momentous transformation involved the lengthening of

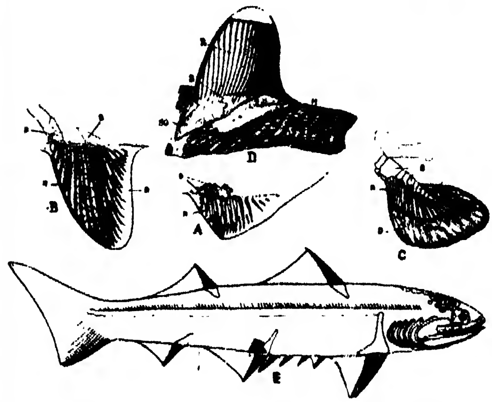


FIG. 7. PROGRESSIVE STRUCTURAL STAGES IN THE FINS OF PALEOZOIC SHARKS

AFTER DEAN.

A. VENTRAL FINS OF DEVONIAN SHARK (*Cladoselache*), SHOWING SEPARATE ROD-LIKE SUPPORTS OF "FIN-FOLD" FIN. B. PECTORAL FIN OF *Cladoselache*, SHOWING PECTORAL GIRDLE AND BASAL PIECES PRESUMABLY DERIVED FROM FUSION OF SEPARATE RODS. C. PECTORAL FIN OF PERMIAN *Pleuracanthus*, SHOWING FULLY DEVELOPED PADDLE-LIKE FIN WITH JOINTED AXIS. D. PECTORAL FIN OF *Cladoselache*, PARTLY COVERED BY PRESERVED MYOMERES. E. RESTORATION OF GENERALIZED ACANTHODIAN BY DEAN.

the hind limbs in man and many other changes in the relative proportions of his thumb, great toe, hip bone, etc.

The history from fish to man is epitomized in a series of paintings by F. L. Jaques (Fig. 8) brought together under the heading, "Students in Nature's

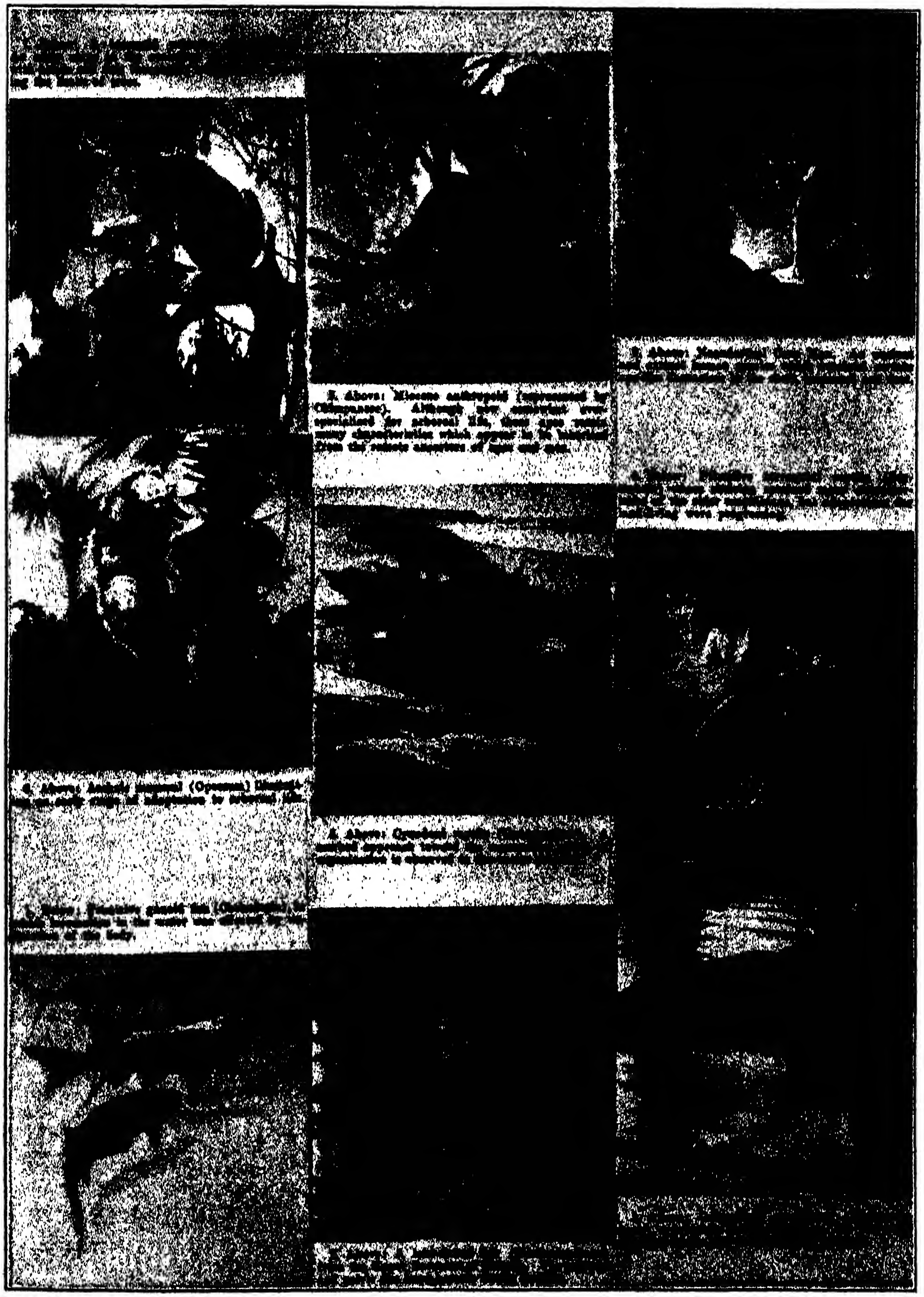


FIG. 8. STUDENTS IN NATURE'S TRAINING SCHOOL

A SERIES OF PAINTINGS BY F. L. JAQUES, ILLUSTRATING THE PRINCIPAL STAGES, FROM FISH TO MAN, IN THE EVOLUTION OF THE LOCOMOTOR APPARATUS AND THE DEVELOPMENT OF THE UPRIGHT POSTURE.

Training School.'' Without at all subscribing to the Lamarckian doctrine, we may recognize the fact that one kind of environment after another was mastered on the long road upward and that man has inherited both in his anatomical make-up and in the simpler patterns of his nervous reactions some of the more fundamental adjustments learned in earlier environments. For example, his semi-circular canals have served him from the fish stage onward with relatively little change, while the paired paddles have been made over into jointed stilts.

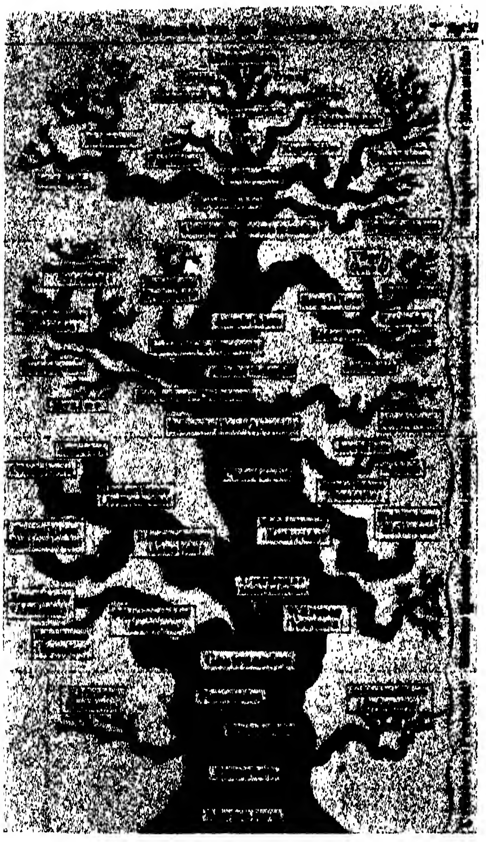


FIG. 9. HAECKEL'S CHART ILLUSTRATING THE PEDIGREE OF MAN

So much for the general outline of evolution from fish to man.

The question of the origin of man has always been closely tied up with the question, ''Which are man's nearest living relatives?'' The earlier anthropogenists, including Darwin, Haeckel and Huxley, did not hesitate to accept the existing anthropoid apes as being the specialized descendants of the common ancestors of apes and man. That this conclusion was correct has been confirmed by thousands of special investigations in many fields. In Haeckel's chart (Fig. 9) man is for convenience placed at the center of the tip of the tree, although Haeckel was anything but anthropocentric in his teachings. In a wall painting (Fig. 10) which we recently installed in the American Museum of Natural History mankind is shown as a curious side-shoot from the anthropoid stock, distinguished by a marked change in his locomotor habitus. His nearest living relatives are there pictured as the chimpanzee and the gorilla.

The general position of man in geologic time is indicated in the chart shown in Fig. 11, which is based on the researches of many vertebrate paleontologists. Here we see that long before the close of the Paleozoic era, some two hundred million years ago, the reptilian stock had already given off a great side branch, the mammal-like reptiles, one group of which eventually gave origin to the mammals. The monotremes, the multituberculates and the marsupials are earlier branches. The placentals are not known until Upper Cretaceous times, near the close of the so-called Age of Reptiles. By Lower Eocene time the placental mammals were already represented by known ancestors of horses, cattle, carnivores, insectivores, etc., as well as by a host of wholly extinct forms. The earliest primates—primitive lemuroid and tarsioid forms—also date from the Lower Eocene; monkeys and apes date from the Oligocene. Man, however, is not represented by admitted flint artifacts until late in the Pliocene. Thus so

FIG. 10. MAN AMONG THE PRIMATES
(WALL PAINTING IN THE AMERICAN MUSEUM OF NATURAL HISTORY).

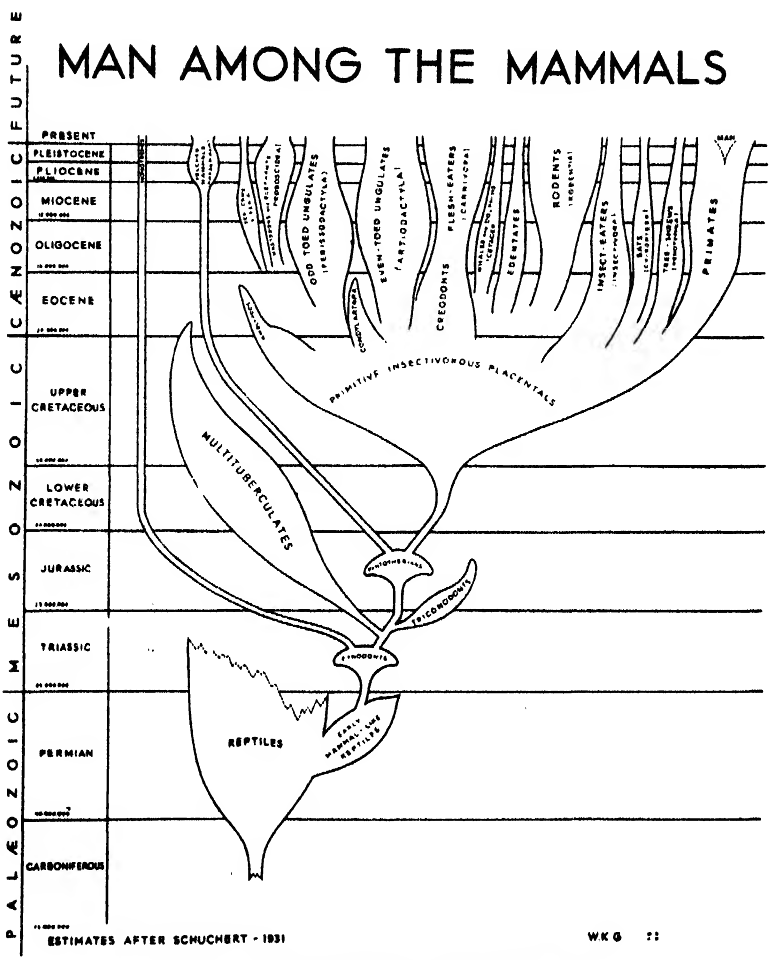


FIG. 11. MAN AMONG THE MAMMALS

far as the record goes it affords no support for those who postulate the separateness of man in early Tertiary times.

The more exact time when the parting of the ways between the nascent Hominidae and their simian relatives took place is still in dispute. Some, like Professor Osborn, believe in the separateness of mankind in early Tertiary times, possibly even in the Lower Eocene. At the other extreme we have Professor Weinert of Germany and Dr. Broom, the eminent paleontologist of South Africa, who date the separation not earlier than in the late Pliocene epoch. I have maintained that the date of the separation of the two families is far less certain than the fact that the separation once took place. The existence of a wide range of fossil anthropoid apes from France to India during late Tertiary times and the fact that some of them are difficult to distinguish in tooth and jaw structure from certain human types, suggest that the separation may already have been under way in late Miocene times, perhaps ten million years ago.

The human foot has afforded great comfort to those who want to separate man as widely as possible from the an-

thropoid apes, for it is obvious that the ape foot is a grasping, tree-climbing type, with a sharply off-set great toe, whereas the human foot is adapted for bipedal erect progression and the great toe is nearly parallel with the remaining toes. There is, however, a great deal of anatomic evidence for the view that the human foot has been derived from an ape-like type chiefly by the drawing together of the great toe and the other toes, which have at the same time become bound together by connective tissue. This tissue has eventually formed the deep transverse metatarsal ligament that ties the great toe to the others.

In spite of its obvious differences the human foot shares with the anthropoid foot a fundamental dichotomy, since the great toe, although tied in with the other toes, yet contrasts widely with them in size and strength. To make a long story short, it can only be said that in beautiful dissections of the feet of various anthropoids and man my colleague, Mr. Raven, has supplied the most cogent evidence that the human foot shares with that of the anthropoid ape a striking unity of plan joined with modifications in proportions and in details appropriate to its newer method of locomotion.

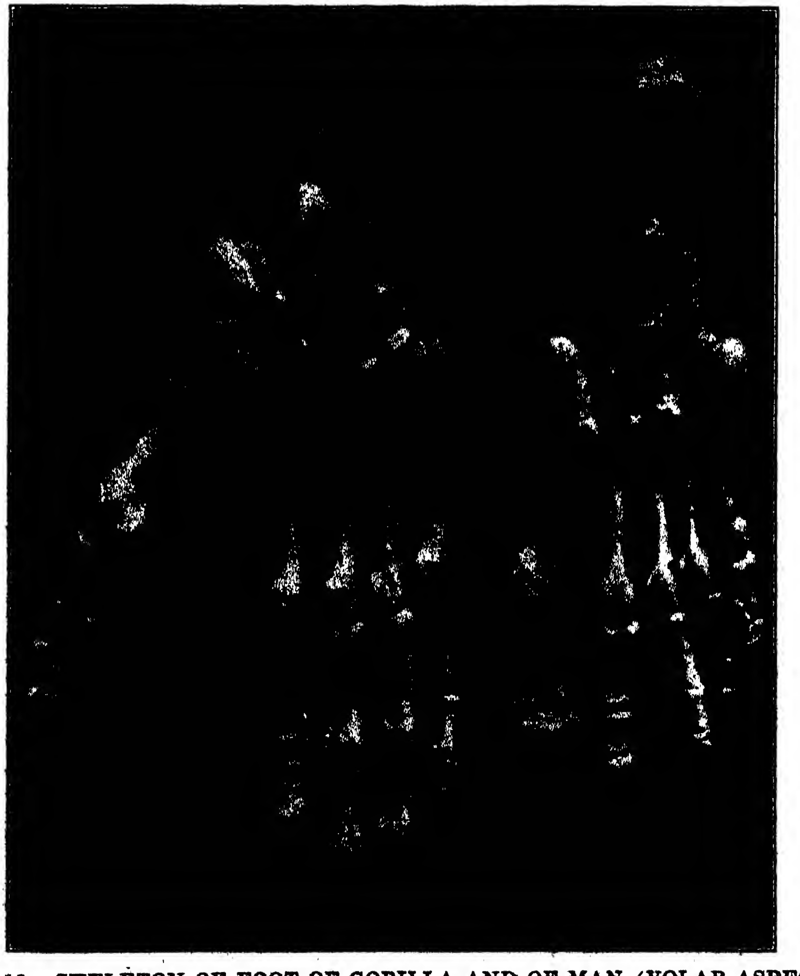


FIG. 12. SKELETON OF FOOT OF GORILLA AND OF MAN (VOLAR ASPECT)

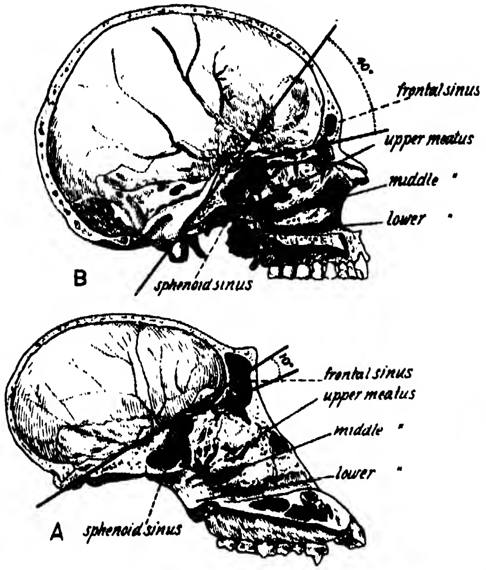


FIG. 13. LONGITUDINAL SECTION OF THE SKULL IN MAN (B) (AFTER CUNNINGHAM) AND CHIMPANZEE (A).

The skeleton of the human hand is built upon the same plan as that of the chimpanzee, save that in man the thumb is larger and the hand as a whole wider. The gorilla hand shows the effect of giantism in widening. To me the evidence suggests that in man the thumb has become markedly enlarged and the hand as a whole shortened and widened. In any case it is a fact that in the an-

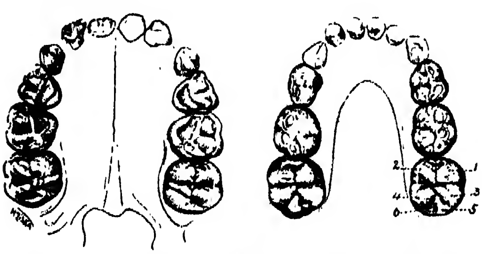


FIG. 14. UPPER AND LOWER TEETH OF *AUSTRALOPITHECUS*

NATURAL SIZE. DRAWINGS BASED ON CASTS AND PHOTOGRAPHS, THE LATTER KINDLY SUPPLIED BY THE DESCRIBER OF *Australopithecus*, PROFESSOR RAYMOND A. DART. THE HINDERMOST TEETH ARE PERMANENT MOLARS; THE OTHERS ARE DECIDUOUS TEETH.

thropoid apes the anterior extremities are true hands rather than fore feet, so that in this respect, as in so many others, the anthropoids anticipate man.

A comparison of half-sections of the skull, along the sagittal plane, of chimpanzee and of man brings out first the agreement in fundamental plan and secondly the expansion of the braincase, the shortening of the upper jaw and

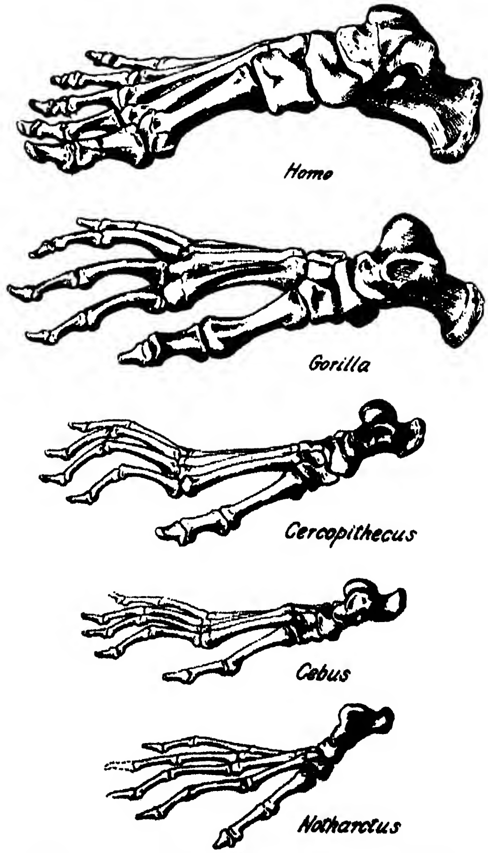


FIG. 15. SKELETON OF THE FOOT, *NOTHARCTUS* TO MAN

vertical expansion of the nasal cavity in man. What more favorable starting-point for the human cranium than the chimpanzee skull could be asked for?

The same story is told by a comparison of the brain, as shown in the figures in Professor Tilney's work on "The Brain from Ape to Man." The human

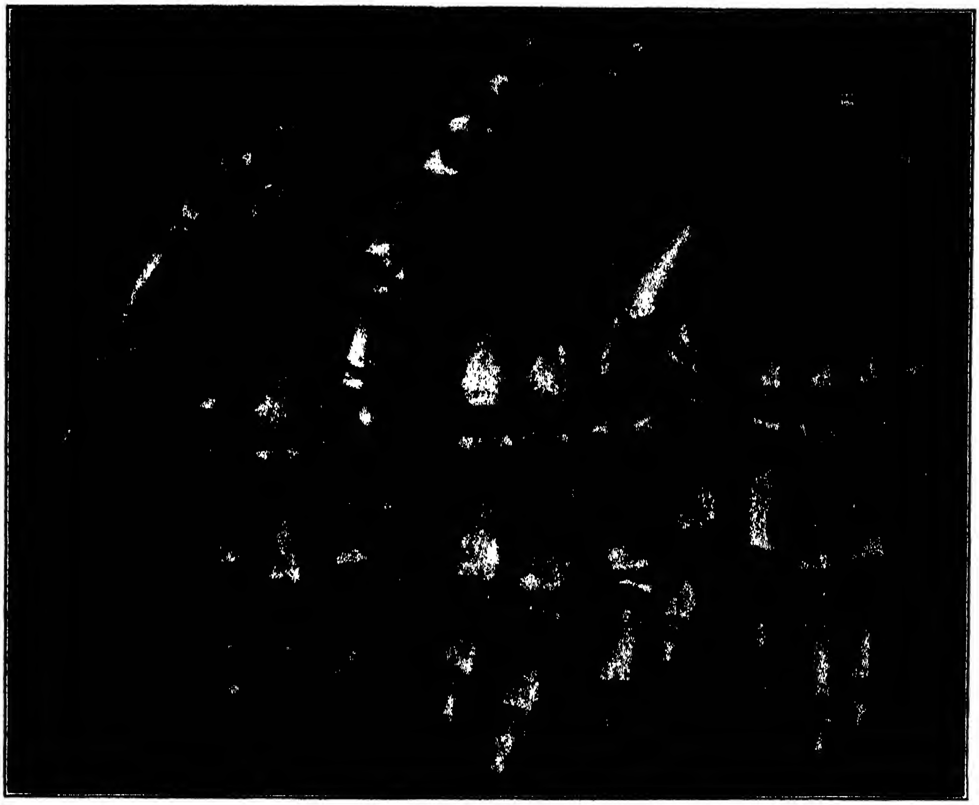


FIG. 16. SKELETON OF HAND OF MAN, GORILLA, CHIMPANZEE (PALMAR ASPECT)

brain is evidently much larger and has a more complexly folded surface than the gorilla brain. The identity in plan of these two brains is even more clearly shown in the basal aspect of the gorilla and human brains. It would be difficult to find a more striking example of agreement in fundamental pattern accompanied by uneven expansion of certain areas in the more advanced type. The same principle is illustrated in cross-sections of the cerebellum of gorilla and man, from Tilney (Fig. 17). Even the nucleus dentatus is strikingly similar in the two forms. From a taxonomic viewpoint such numerous and striking identities in basic patterns can only mean relatively close relationships between the forms compared.

If space permitted I could cite literally hundreds of such agreements between man and one or another of the anthropoids exhibited throughout the skeleton and soft anatomy or in various physiological reactions. This close relationship is especially marked in the fossil *Australopithecus* from South Africa, described in 1925 by Professor Raymond Dart and more recently by the eminent paleontologist, Dr. Robert Broom. A careful study of the details of the deciduous and permanent teeth by my colleague, Dr. Milo Hellman, and myself convinced us that *Australopithecus* in many features of its dentition comes nearer to man than does any other known fossil ape, and that, taken in conjunction with the anatomical evidence

from recent forms, it tends to support the view that the separation between the Hominidae and the Simiidae took place at a relatively late geological epoch. *Australopithecus* tends also to support the view of the late Professor Bolk of Amsterdam, which was that in some respects modern man is a sort of infantilized anthropoid with small jaws and still more swollen brain and braincase.

This leads us at once to the predominant rôle of the brain in human evolution. If we consider the structure and behavior of such a relatively primitive organism as *Peripatus,* we shall note that it moves toward its food, in order, as we say, to seize and eat the food. But please notice that this action appears from our point of view to be directed toward future results, which are the digestion and assimilation of the food and the storage of energy for the running of the vital machinery. While practically all vital reactions have this sort of reference to events in the future, we may also say that a nervous system is of special service in accelerating such adjustments to future situations. In other words, from this point of view a nervous system is on the whole a peculiarly anticipatory or forward-looking system, which prepares for events before they happen. The reason, of course, why actions can be successfully adjusted

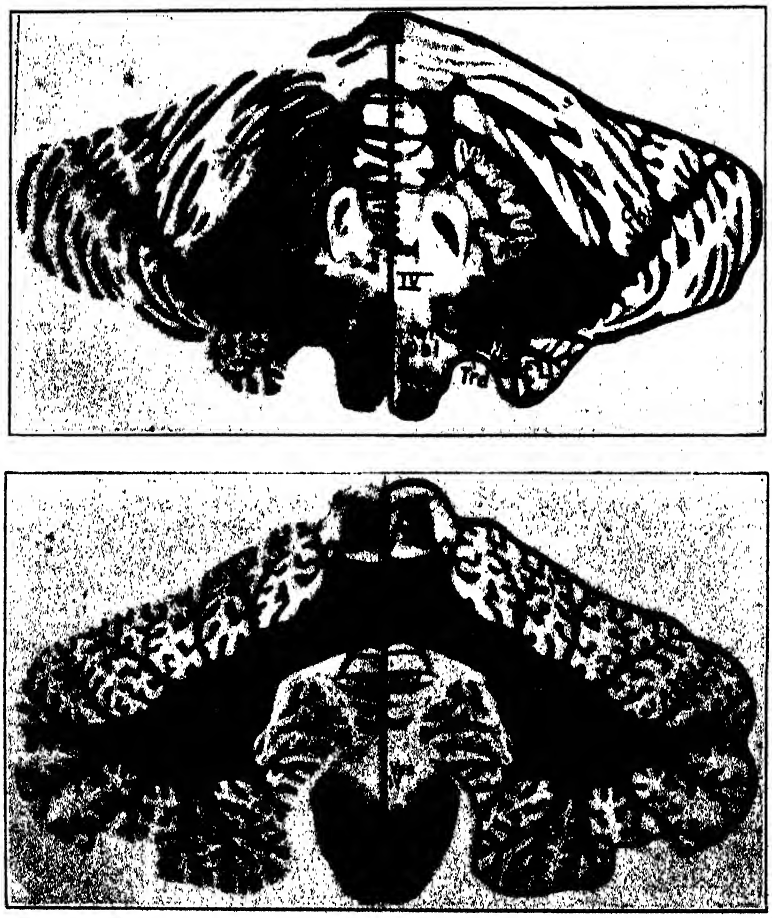


FIG. 17. CROSS-SECTION OF CEREBELLUM OF GORILLA AND MAN
AFTER TILNEY.

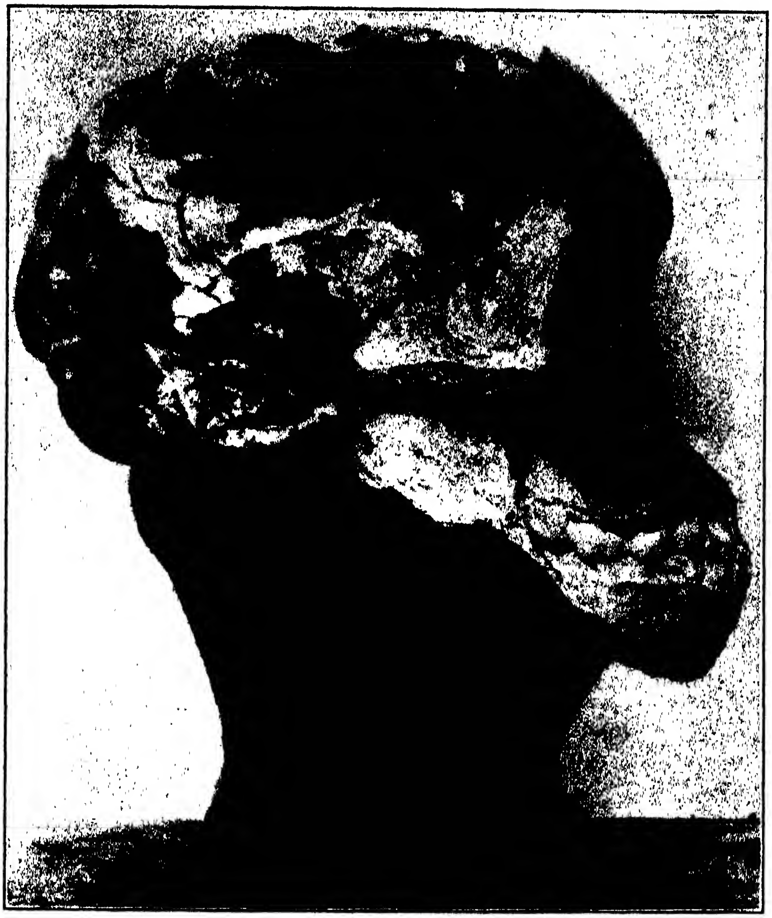


FIG. 18. *AUSTRALOPITHECUS AFRICANUS*
AFTER DART.

to future events is that in a world of day and night and regular seasons future events in the long run are apt to average about the same as past events, so that by at first adjusting themselves to what *has* happened, creatures with nervous systems learn to pick out the signals of events that are about to happen, and finally by natural selection, or what you will, they come into the world wound up to adjust themselves to certain ranges of stimuli.

Paleokinesis, the more direct response to sensory stimuli, is illustrated in the central nervous system of the shark, while neokinesis, the highly indirect and complicated response to sensory stimuli, is illustrated in the functional relations between the neopallium and the older parts of the brain in man. I merely wish to emphasize the idea that with the invention of verbal signals the original simple anticipatory response of the primitive vertebrate became complicated to such a degree that it shifted the evolution of man into wholly new and astonishing patterns. Gone was the age of innocence and simple homely pleasures; selfishness and above all, self-esteem, were magnified and distorted into folly and wickedness. Conditioned responses built up into traditions often

became elaborated into fictitious or conventionalized taboos and other systems of values that have left in them little of the natural relations. The Central Australian native, decked for some ceremony deeply significant to him, pays but little attention to the discomfort of being thickly covered by masses of white clay and vegetation. He probably believes he is a rain god or something of the sort and experiences a grand uplift of "face."

Hence it comes about, through the power of the written and spoken word, that for sheer mass stupidities the like of *Homo sapiens* has never before been seen in an astonished world of reasonably straightforward and honest animals. The only redeeming feature is that often one mass stupidity cancels another, or at least holds it in check.

In spite of all these signs of gradual decline I would not argue that *Homo sapiens*, like Hogarth's flirtatious maid, is tottering to his fall. He may eventually lose his third molars, while his lateral incisors and the terminal joint of his little toe may disappear; he may have adenoids, contracted palate and bad teeth. On the other hand, his brain may become even more swollen (but only if Caesarian operations become common). On the whole, however, as Professor Tilney has noted, it is far more important for him to make better use of the cauliflower-like organ that he already has.

With all his afflictions and stupidities *Homo sapiens* is distributed nearly all over the map, and experience shows that no other animal is so difficult to exterminate permanently. The Chinese for ages have been afflicted with floods, war, famine, pestilence and the native pharmacopeia, but for all that there are still enough Chinese to worry the Japanese.

In short, I have never seen any sufficient reason for assessing *Homo sapiens*, or *Homo* of some new species, as a bad insurance risk for a few million years more, which is but a short period in the history of a genus. Not all the human race will succeed in slaying each other with gas or germs and there will still be relatively honest and unsophisticated folk in Asia or Africa whose descendants will move in and possess the land in their turn.

ARTHROPODS AND THEIR RELATIONSHIP TO DISEASES OF DOMESTIC ANIMALS

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PATHOGENIC bacteria have held the stage of public attention for so many years that they have, to a considerable extent, overshadowed the importance of other organisms responsible for sickness and death. This is particularly true of the biological relationship between insects and insect-borne diseases of man and domestic animals.

Of the various diseases to which domestic animals are susceptible, a surprisingly large number are transmitted by insects or other arthropods, either mechanically, as by carrying infective material on their biting mouth-parts, or by the fact that they act as intermediate hosts for the complete development and continuity of certain disease-producing organisms.

It is interesting to note that a number of diseases of animals can be transmitted only through the instrumentality of specific arthropod hosts. For instance, there are many species of ticks infesting wild and domestic animals, yet there is only one species—at least on this continent—that is capable of transmitting the disease of cattle commonly known as "Texas fever."

If it were not for certain insects known to be carriers of infection, a number of diseases of domestic animals could not and would not exist. This knowledge is of great importance and practical value, because it enables the veterinarian, live-stock sanitation and owner to control, and in many cases to eradicate a number of diseases of animals, by attacking or destroying arthropods responsible for their transmission.

The species of arthropods responsible for the transmission or spread of animal diseases is quite large—too large in fact to discuss in detail in an article such as this, a general review of species that are of particular interest to persons who are directly or indirectly connected with or interested in the live-stock industry in one or more of its various branches. What may be facetiously termed "the rogue's gallery of insects" is herein presented with some semblance of zoological order.

CRUSTACEANS

Crustaceans are not a very important group of arthropods so far as the transmission of animal diseases is concerned. However, they can not be entirely ignored, because some species serve as intermediate hosts for a few helminth parasites of animals. For instance, certain species of crabs and cyclops (*Copepoda*) are intermediate hosts of various species of tapeworms that infest ducks, geese and other aquatic birds. Cyclops are also indirectly responsible for the transmission of a species of tropical roundworm called "the Guinea or Medina worm" (*Dracunculus medinensis*), which invades the subcutaneous tissues of hogs, horses, cattle, sheep, goats and man. The infestation of animals is brought about by drinking water containing cyclops, the bodies of which contain embryo worms. Guinea worms are of far more medical importance to man than to the lower animals.

Another crustacean, known in the United States as "the sow bug" and in

England as "the wood louse," has been found to be the intermediate host of the spiral stomach worm of chickens (*Dispharynx spiralis*). This worm, found in the tissues of the glandular stomach of chickens, turkeys and pigeons, does a considerable amount of damage. In game birds, two sow bugs, namely, *Porcillio scaber* and *Armidillium vulgare,* serve as intermediate hosts for the spiral stomach worm—the same species that infests chickens.

INSECTS

Insects, as would naturally be expected because of their relatively large numbers, form the major portion of the arthropods affecting domestic animals. Six orders of insects are included in this category, namely: Odonata (dragonflies); Malophaga (biting lice); Orthoptera (roaches, etc.); Diptera (flies); Siphonaptera (fleas); and Coleoptera (beetles).

Odonata (dragon-flies): Dragon-flies, snake doctors, devil's darning needles, etc., are a few of the "charming" names given to this order of useful insects. They are of little importance as disease vectors, although Kotland and Chandler have reported that dragon-flies were intermediate hosts of a newly discovered species of fluke (*Prosthogonimus* sp.), which inhabit the oviducts of poultry. These investigators found encysted larvae of this fluke in adult dragon-flies and in their nymphs. Experimental proof that dragon-flies are capable of transmitting flukes was demonstrated by feeding birds infested dragon-fly nymphs, after which adult flukes were found in the oviducts of these birds.

Malophaga (biting lice): Many people who own pets (and possibly many who do not) are familiar with the discomfort produced by biting lice. The ill effects resulting from lice in domestic animals are not entirely due to irritation; there are several species that are of considerable importance as carriers of certain animal diseases. For instance, the rabbit louse (*Haemodipsus ventricosus*), is known to transmit tularemia to both man and lower animals. There is also evidence that the short-nosed louse of cattle (*Haematopinus eurysternus*) is capable of transmitting anaplasmosis—a disease of cattle caused by a protozoan parasite which invades the red blood cells. At least Stiles was able to produce the disease experimentally in a young guinea-pig by injecting it with macerated bodies of lice taken off cattle suffering from anaplasmosis. Other arthropods, chiefly ticks, are thought to be principally responsible for the transmission of this disease.

One of the two species of lice that are commonly found on dogs, namely, the biting louse (*Trichodectes latus*), is of particular interest because it is one of the intermediate hosts of the double-pored tapeworm of dogs (*Dipylidium caninum*), which inhabits the small intestine, and also because it was the first arthropod recognized to be the intermediate host of a parasitic worm. Lice become infested with larvae of this dog tapeworm by swallowing them while feeding on the contaminated skin of dogs. Dogs in turn become infested by swallowing lice containing encysted embryo tapeworms or larvae, usually at the time they are biting themselves to allay irritation.

It might be of interest to state that the double-pored tapeworm of dogs occasionally develops in man, particularly in children, who become infested by accidentally swallowing infested lice, which presumably get into their mouths while fondling dogs, or possibly by placing their fingers in their mouths; or the infestation may be conveyed by food or water. It can then be seen that while "Junior and Towser" may represent an

ideal bond of friendship, this may not always be to Junior's advantage. However, infestation by this dog tapeworm is so rare in man as to be of little concern, although it is always advisable to be on the watch. Aside from the slight risk of transmission to some member of the family, treatment should be given for the elimination of tapeworms in dogs whenever they are found to be infested.

Besides the biting louse, the flea is an intermediate host of the double-pored tapeworm of dogs. This will be discussed later.

Orthoptera (grasshoppers, cockroaches, etc.): One would hardly suspect grasshoppers of having any connection with the transmission of disease. However, not only grasshoppers, but cockroaches serve as intermediate hosts for at least six species of parasitic roundworms of domestic fowl and game birds. Two species of grasshoppers, *Melanoplus femurrubrum* and *M. differentialis* (and probably a number of others), serve as intermediate hosts for *Tetrameres americana,* a roundworm inhabiting the glandular stomach or proventriculus of chickens; also for the spiral stomach worm (*Cheilospirura hamulosa*) of chickens, and (*C. spinosa*) of gallinaceous birds. Cockroaches also play the rôle of intermediate hosts for at least three species of roundworms of poultry and game birds.

The tropical cockroach (*Pycnoscelus surinamensis*), which ranges (under natural conditions) as far north as the Carolinas, serves as intermediate host for a curious worm called "Manson's eye worm" (*Oxyspirura mansoni*), which is found under the nictitating membrane of the eyes of chickens. So far this worm is chiefly confined to the states of Florida and Louisiana, but with the help of accommodating cockroaches and modern transportation facilities it may have an opportunity to travel farther afield.

The European cockroach (*Blatta germanica*) has recently been found to be the intermediate host for a parasitic roundworm, technically known as *Seurocyrnea colini,* which invades the wall of the glandular stomach or proventriculus of game birds. According to Dr. Eloise B. Cram, this worm has not been reported from any other country than the United States.

Diptera (true flies): Flies are undoubtedly one of the worst pests that wild and domestic animals have to contend with. Not only do flies cause continuous torment to animals during the warmer months, but they are also responsible for the transmission of a number of specific animal diseases, while the larvae of a number of species produce extensive and often fatal wounds by feeding on skin, flesh and other tissue.

Several species of flies are of considerable economic importance as intermediate hosts for parasitic worms; for instance, two or more species of poultry tapeworms (*Choanotaenia infundibulum* and *Davainea cesticellus*) are transmitted by the common house-fly. In horses, three species of stomach worms, *Habronema muscae, H. megastoma* and *H. microstoma,* are transmitted by flies. The first two pass their larval stage in the grubs or larvae of house-flies, while the latter is transmitted directly by the stable-fly (*Stomoxys calcitrans*).

Flies belonging to the order Muscidae are represented by a number of very harmful species. None, however, are of more historical, economic or medicinal importance than the well-known tsetse flies which are responsible for the transmission of African sleeping sickness—a disease which renders vast areas of Central and West Africa uninhabitable. The African type of sleeping sickness

(which should not be confused with the so-called sleeping sickness or encephalitis of temperate climates) is caused by an elongated microscopic animal parasite (trypanosome), which invades the blood stream.

This parasite is principally transmitted, at least in Africa, by various species of tsetse flies on which it depends for the completion of its life cycle and its transmission to other susceptible victims. Both trypanosomes and tsetse flies are of particular interest in medical history because the cause of African sleeping sickness was not clearly understood until Sir David Bruce, in 1896, discovered that nagana,[1] an African disease of horses, mules, cattle and other domestic animals, similar to the human type of infection, was caused by a trypanosome parasite in the blood. This parasite was later named in his honor as *Trypanosoma brucei*. By patient observation Sir David also discovered that nagana was spread by the tsetse fly (*Glossina morsitans*) from sick to healthy animals. Armed with this knowledge the cause of the human type of trypanosomiasis was a matter of comparatively easy solution.

There are several types of trypanosomiasis in both man and animals, all of which are transmitted by tsetse flies. However, as the general characteristics and method of spread of the various types of trypanosome infection are more or less alike, there seems little need to go into further detail.

Trypanosome infections of animals are not always transmitted by tsetse flies. In India and the Orient, a disease called "surra," affecting horses, mules, camels, elephants and other wild and domestic animals, is transmitted by several species of horse-flies or tabanids. Murrina of mules in Central America and *mal de caderas* (disease of the hindquarters) in South America are both caused by trypanosomes and are transmitted from one animal to another by horse-flies and other blood-sucking diptera. One genus of horse-flies, namely, *Chrysops* (deer-flies), is responsible (together with several other species of arthropods) for the transmission of tularemia. Wild rabbits are thought to be the principal reservoir of infection, and wood-ticks are the principal carriers.

Aside from the transmission of infectious diseases by diptera, several species of muscid flies are of tremendous economic importance because they do considerable damage in their larval stage.

Those who have lived in rural sections of the southeastern United States are probably familiar with the grubs or larvae of the screw-worm fly (*Chrysomyia macellaria*), which inflicts such terrible wounds on various species of live stock. The female screw-worm fly lays her eggs on or near cuts or abrasions on the body. It only requires a few days for these eggs to hatch into grubs, which immediately commence to burrow into sound tissue. The discharge of bloody serum from the infected parts enables the owner or his assistants to easily detect the presence of screw-worms.

There are a number of other muscid flies, known collectively as "blowflies," which are of considerable economic importance to live-stock owners, particularly to sheep-raisers, because they lay their eggs on soiled wool, chiefly around the vent or hindquarters. The larvae of these flies live on the soiled wool and in the flesh, causing the fleece to become of little commercial value. In addition to this, the loss of time and expense in picking out and treating infested sheep adds considerably to the cost of production.

[1] According to Sir David Bruce, "nagana" is a Zulu word which refers to the state of depression and weakness characteristic of the disease.

Two other muscid flies, known as ox warbles and gadflies (*Hypoderma lineata* and *H. bovis*), cause an annual loss of approximately fifty million dollars in the United States, according to an estimate made by the U. S. Department of Agriculture. The principal damage results from holes made through the hide of the animal by the larvae in working their way out. The life cycle of warble flies is rather complicated, but very interesting. Briefly, the eggs are generally laid on hairs on or near the heels of cattle. The grubs soon hatch, after which they penetrate the skin and work upwards through the tissues of the body until they finally reach the back. Here swellings are produced, through the top of which the larva cuts a hole and finally emerges and falls to the ground, to change to pupa or chrysalis, emerging as an adult fly the following summer.

The holes in the skin naturally cause the hides to be of little value for the manufacture of leather, but this is not the only source of loss; the female flies in depositing their eggs frighten the cattle so much that many are injured during stampedes, running into trees or other objects, breaking their legs, falling off cliffs, etc.

The northern gadfly (*Hypoderma bovis*), while not so common or so widespread in range as *H. lineola,* nevertheless causes a greater degree of excitement in cattle while attempting to deposit eggs on hairs on the heels of its bovine victim. This, no doubt, is due to the fact that its attack is more vicious and the noise of its rapidly moving wings is of a higher pitch.

In Alaska and other parts of the northern hemisphere, reindeer are attacked by another gadfly (*Oedemagena tarandi*), the larvae of which emerge through holes in the skin of the back, like the larvae of the gadflies of cattle. Apparently the reindeer fly was introduced into Alaska by the importation of reindeer from northern Europe.

In Russia, a gadfly (*Rhinoestrus nasalis*) parasitizes the nasopharyngeal region of horses. It may also attack man. When this occurs it is said to deposit its eggs almost instantaneously in the eyes. The larvae cause intense pain and conjunctivitis, and if not removed before too much tissue damage has resulted, permanent blindness may follow.

In tropical America we also have another curious and enterprising representative of the gadfly family in *Dermatobia hominis.* The female of this species, instead of laying eggs in the usual orthodox manner, catches mosquitoes and blood-sucking flies and attaches eggs to the sides of their bodies. As soon as the victimized insects alight on cattle to feed on their blood, the eggs, stimulated by the warmth of the animal's body, hatch almost immediately, and the young grubs transfer themselves from their temporary insect host to the skin of their final host, through which they burrow. Lumps or tumors are produced by the larvae on the animal's back, through the top of which holes are cut similar to those produced by the larvae of the cattle gadfly. The remainder of their life cycle is about the same as that of other species of gadflies.

Another example of harmful fly larvae is to be found in the bot-flies (*Gastrophilus*). The larvae of bot-flies inhabit the stomach and digestive tract of horses, mules and other species of equidae. In the United States there are three species of bot-flies, namely, *Gastrophilus intestinalis, G. nasalis* and *G. haemorrhoidalis.*

The eggs of bot-flies are laid on hairs on different parts of the body, the area selected being characteristic of the species which lays them. In depositing eggs, the female fly produces a humming noise with her wings, which, in the case

of the nose bot-fly (*G. haemorrhoidalis*) and the throat fly (*G. nasalis*), causes considerable excitement in horses; in fact, nervous animals frequently become unmanageable, with the result that "runaways" and accidents are of common occurrence during the fly season.

The larvae of bot-flies get into the digestive tract of horses and mules when the animals bite or lick themselves. However, in the case of the throat bot-fly, it is thought that the larvae penetrate the skin and tissues and finally enter the esophagus and stomach under their own power, as it were.

Bot-fly larvae produce considerable damage after they attach themselves to the mucous lining of the stomach and intestine, by interfering with the digestive functions and also by causing irritation at the place of attachment. Sometimes pus-producing bacteria may enter, causing abscesses which may destroy so much tissue that perforation of the stomach wall follows. In such cases peritonitis invariably develops, terminating in death.

The larvae are easily destroyed by the administration of carbon disulfide during December, January and February. This drug kills not only the bots but also large roundworms or ascarids and stomach worms (*Habronema*).

In Iowa and Illinois, excellent results have been obtained in controlling bots in horses by the cooperative efforts of agricultural extension workers, local veterinarians and horse-owners. The principal object in this work is to treat as many horses and mules in as wide an area as possible so that the bots will be destroyed before they have an opportunity to develop into flies. In other words, it is much easier to control or destroy the larvae than the flies—which are of course able to travel comparatively long distances and deposit thousands of eggs. Horse-owners who have experienced the benefits resulting from community bot-eradication work (call it state medicine, if you will) are very enthusiastic because they realize that treated horses and mules can be kept through the winter in better physical condition and with less feed and consequently much less expense. It may also be said that when a sufficient number of owners have had their animals treated in a certain community, the number of bot-flies will be so reduced as to enable teams to work the following summer without being constantly subjected to attacks of bot-flies. Individual farmers or team-owners at times refuse to enter into a cooperative scheme of this kind. The horses and mules of these recalcitrants serve as incubators for bot-flies, which, not having the power of discrimination, are as likely to lay eggs on the animals of the most enthusiastic public-spirited farmers as on those owned by the "rugged individualists."

In sheep there is another species of bot-fly, namely, *Oestris ovis*, which has somewhat different habits, in that, instead of depositing eggs on the hair or wool, it lays them in the sheep's nostrils. The eggs are ready to hatch as soon as they are deposited, so the young larvae lose no time in working their way up the nose into the nasal sinuses, where they attach themselves to the mucous membrane by means of hooklets. So much irritation is produced by these grubs that more or less characteristic symptoms are exhibited, such as violent sneezing, stamping on the ground, discharge from the nose, loss of flesh, etc.

Simulidae (black flies or buffalo gnats): Readers who are trout fishermen or who camp near streams in the spring will need no introduction to these insects, because their sharp and irritating bites are sufficient to make a lasting impression on the memory. Black flies are a serious menace to live-stock owners during the early part of the year. In

fact, the blood extracted and toxins or poisons injected by these flies cause serious and sometimes fatal sickness, even in larger animals, such as horses, mules and cattle. Black flies are also responsible for the spread of different communicable diseases, so that they are of particular economic importance. In ducks, a disease caused by a protozoan parasite (*Leucocytozoon anitis*) is spread by black flies, according to Dr. E. E. O'Roke, of the School of Forestry and Conservation of the University of Michigan. This disease has caused a considerable reduction in the numbers of wild ducks at Douglas Lake and elsewhere in Michigan, according to this same observer. The parasite is transmitted from sick to well ducks by the bite of black flies. Adult ducks harboring the parasite are apparently little affected, but ducklings succumb in large numbers. Domestic ducks are also affected. Farmers report losses of from 70 to 100 per cent.

Turkeys suffer from a similar disease, which is also transmitted by black flies. The organism in this case is *Leucocytozoon smithi.* It produces symptoms of muscular incoordination, sleepiness, coma, exhaustion and sometimes convulsions.

In horses, black flies are responsible for the transmission of a roundworm (*Onchocera volvulus*), which is associated with a rather common disease of the withers of horses known as fistula. What part this parasite plays in the pathology of fistulous withers (and a similar condition affecting the head, back of the ears, known as poll evil) has not yet been definitely determined.

Blacklock has shown that the microfilaria of *O. volvulus* may develop in black flies; consequently, these insects, together with other diptera, such as tabanid flies, mosquitoes, etc., may be responsible for the transmission and spread of both fistula and poll evil among horses and mules.

Before dismissing black flies or buffalo gnats as vectors of animal diseases, it may be as well to state that anthrax, an exceptionally virulent disease of live stock in many of our southern states, is thought to be carried by these insects as well as by other blood-sucking flies.

Culicidae (mosquitoes): It has recently been discovered that mosquitoes belonging to the genera Culex and Aëdes are responsible for the spread of fowl pox, a very common and harmful disease of chickens and pigeons. Mosquitoes also act as vectors of avian malaria and possibly coccidiosis.

Fowl pox and other diseases are probably transmitted mechanically by mosquitoes—differing in this respect from the transmission of human malaria, which requires the completion of the sexual cycle of the malaria parasites inside the body of the mosquito before becoming infective for man.

One of the most interesting and important diseases carried by mosquitoes, so far as dog-owners are concerned, is heartworm infestation. Within the last few years dog-owners have become greatly concerned about the rapid spread of these parasites. The first reports of the occurrence of heartworm infestation in dogs in the United States were made from Florida. Now heartworms are found in dogs in states much further north. The spread of this parasite is undoubtedly due to the fact that dogs shipped south for the hunting season become infested and on their return to their northern homes act as centers of infestation for other dogs. As it is only necessary to have infested dogs and the presence of mosquitoes to make outbreaks possible, it will not be at all surprising if heartworm in dogs becomes far more wide-spread than it is at present.

Heartworms in their mature stage inhabit the right half of the heart. The parasite is viviparous, but the embryos are to be found in the general circulation. This is what makes it possible for mosquitoes to take up the embryo worms while feeding on infected dogs and to transfer them to other dogs.

Symptoms produced as a result of heartworm infestation are not sufficiently characteristic as a rule to make a diagnosis easy, but a microscopic examination of the blood from suspected dogs has, of course, diagnostic value.

Up to within a short time ago no cure for canine heartworm infestation was known until Dr. J. M. Hays, of the Alabama Polytechnic Institute of Auburn, Alabama, reported, through the medium of a veterinary journal (*Veterinary Medicine,* Apri', 1933), that he had found a double antimony salt to produce good clinical results when injected intravenously.

More recently, the Zoological Division of the Bureau of Animal Industry announced that two of their veterinarians, namely Drs. W. H. Wright and P. C. Underwood, had tested the efficacy of a complex antimony compound called "Fouadin" and that it had proved effective as a remedy for heartworm infestation in dogs. This work, I understand, was assisted by a fund raised by the Sportsman's Gun-Dog Club of Philadelphia, so that this organization should receive full credit for their valuable aid.

Major R. A. Kelser, of the Army Medical School, recently discovered that the mosquito (*Aedes aegypti*) is capable of transmitting equine encephalomyelitis, commonly known as "horse plague." This disease is caused by a filterable virus and was first reported in the San Joaquin Valley in California during the summer of 1930. Since that time the disease has become rather widespread and is causing considerable loss to horse-owners.

Hippoboscidae (sheep-ticks): Sheep-ticks, as the reader is probably aware, are not true ticks at all, but degenerate flies living a parasitic life on the bodies of sheep. There are many species of hippoboscid flies, a number of which are found on birds, particularly owls and hawks. The sheep-tick, while a blood-sucker, strangely enough does not transmit any parasite known to be harmful. Nevertheless, in Australia, sheep-ticks are known to transmit a non-pathogenic protozoan parasite (*Trypanosoma melaphagum*), which is only of academic importance to students of parasitology. Sheep-ticks, even though they are not known to transmit disease, are nevertheless a serious menace to sheep-breeders because they cause considerable irritation, restlessness and loss of blood in sheep, which as a consequence rapidly fall off in flesh and in general physical condition.

Another hippoboscid fly, known as the pigeon fly (*Pseudolynchia maura*), causes pigeon-fanciers much trouble and loss. Unlike the sheep-tick, this particular fly is equipped with wings which enable it to make short flights from one bird to another. The pigeon fly is not only of considerable economic interest to pigeon-fanciers because of its irritating and blood-sucking habits, but it is also of importance because it is a carrier of pigeon malaria. This disease causes much sickness and many deaths in pigeons, but its control is confined almost entirely to the eradication of pigeon flies, which are readily destroyed by the application of pyrethrum powder and other insecticides in addition to the frequent cleaning up and removal of droppings, etc.

Another hippoboscid fly similar to the pigeon fly, called *Lynchia hirsuta,* is

found on California Valley quail. This fly also transmits a blood protozoan parasite which causes the death of a great many quail, particularly young birds, which seem to be more susceptible to the disease than older birds.

Siphonaptera (fleas): Fleas are of tremendous importance to the human medical entomologist because they spread bubonic plague, but, so far as the veterinarian and the live-stock owner are concerned, they are (with the exception of the chigoe) of little importance other than that they cause considerable annoyance to live stock. The principal interest in fleas, so far as the transmission of disease in domestic animals goes, is that they act as intermediate host for the double-pored tapeworm of dogs (which is also carried by dog and cat lice, as mentioned in a previous paragraph). Fleas in the larval stage become infested with the embryos of the double-pored tapeworm by swallowing the tapeworm eggs mixed with débris on which the flea larvae feed. The embryo tapeworms are therefore carried over to the adult flea at the time of metamorphosis.

The chigoe (family *Tungidae*) of the Tropics causes a great deal of annoyance and damage to dogs by penetrating the skin between the toes, producing sores similar to those occurring in man from the same source. Professor Frederick Gaige, of the University of Michigan, informed the writer that he had found dogs to be very badly infested with chigoes in Mexico and in Central America. The female chigoe in man usually burrows under the toe nails in order to lay her eggs; while on dogs, as already stated, the flea penetrates the skin between the toes, causing a painful swelling which may become infected with pus-producing bacteria so that serious consequences may follow.

Coleoptera (beetles): While beetles are represented by more species than any other order of insects, they are of little if any importance as vectors of disease other than as intermediate hosts for a rather limited number of parasitic worms that infest animals. One of the most important and interesting occurrences in this connection is the transmission of the thorn-headed worm of swine with the rather awe-inspiring technical name of *Macracanthorhynchus hirudinaceus,* by May-beetles or June-bugs (chiefly *Lachnosterna*). This worm, which seems to occupy an intermediate position between tapeworms and roundworms, attaches itself in its mature form to the mucous membrane lining the small intestines of hogs, by five rows of strong hooks on the head end of its body. As a rule, thorn-headed worms are not ranked as of major importance, but they nevertheless cause unthriftiness and digestive disturbances in hogs. May-beetle grubs ingest the eggs of thorn-headed worms passed out of the body of infested hogs, mixed with the feces. After hatching inside the digestive tract of the May-beetle larvae, the embryo worms become encysted in the muscles, and are released only when the grub or adult beetle is swallowed by hogs. Both May-beetle adults and larvae act as intermediate hosts. Hogs readily become infested because they are very fond of May-beetle grubs and will root up considerable pasture land in their eagerness to find them. Knowing this, hog-raisers often place a ring in the tips of hog's snouts in order to prevent them from rooting—which, whether the owner is aware of it or not, goes a long way to prevent swine from becoming infested.

Certain species of dung beetles also act as intermediate hosts for a rather unimportant roundworm of poultry and game birds technically known as *Gongylonema ingluvicola;* also for a roundworm of the same genus inhabiting the mucous and submucous membranes of the esophagus

of sheep and cattle, namely, *Gongylonema pulchrum* (scutatum). Three poultry tapeworms are also known to be transmitted by various species of beetles, all of which are of more or less economic importance to the poultry raiser.

In addition to the transmission of parasitic worms by beetles, the rose-chafer (*Macrodactylus subspinosus*), causes poisoning in young chickens under ten (10) weeks of age. The symptoms produced are drowsiness, weakness of the legs, paralysis and death. Readers who raise poultry should keep this fact in mind, as it may prevent avoidable loss in case young chickens are kept where there are rose bushes infested with these beetles.

Acarina (Mites and Ticks)

The order *Acarina* contains species of arthropods that are of tremendous importance to the live-stock owner, not alone because many of them cause considerable damage due to their blood-sucking and irritating habits, but because a number of species are carriers of fatal diseases of domestic animals similar in nature to malaria in man. By far the most important tick from an economic point of view in the United States is the southern cattle tick (*Boophilus annulatus*), because it alone of all species in this country is capable of transmitting Texas or splenic fever to cattle. The microorganism causing Texas fever (*Babesia bigeminum*) is a protozoan which invades and destroys the red blood-cells. Texas fever is usually fatal in from 10 to 90 per cent. of non-immune cattle and is one of the principal reasons why cattle-raising has not been more profitable or more highly developed in many of the southern tier of states where the tick is common.

Native cattle that have grown up with ticks, and consequently have been exposed to infection at a very early age, do not usually show any appreciable effect so far as Texas fever is concerned, although they act as reservoirs of infection. The principal damage done to immune cattle is due to the constant irritation by the ticks, and the loss of blood, which may be enormous; for instance, a single female tick may gorge itself on blood until it becomes one hundred times its original size.

The loss in weight and physical condition, shrinkage in milk production in the case of milk cows and death from weakness and exhaustion are the chief forms of damage done by ticks to immune cattle.

The eradication of Texas fever ticks by federal, state and county control measures is one of the most outstanding feats of successfully applied medical entomology in any country. Previous to the initiation of control measures in 1906, Texas fever ticks were to be found ranging as far north as Virginia and as far west as California. In twenty-eight years, federal and state forces have successfully eradicated this parasite from all but comparatively small sections of Florida, Louisiana and Texas. It is expected that if the work continues as rapidly and as successfully as it has in the past the United States will be entirely free of Texas fever ticks within a very few years. Parasitologists who desire specimens of *B. annulatus* had better lay in large series while the supply lasts; otherwise they may have to go to Mexico or to Central America for them.

Aside from the fact that the almost total eradication of the Texas fever tick from U. S. territory is an accomplishment to be proud of, it also has a very illuminating economic side. For instance, in a recent article on Texas fever in the April (1934) issue of *The North American Veterinarian,* Dr. M. C. Hall, chief of the Zoological Division, Bureau of Animal Industry, pointed out that in

1906 it was estimated that Texas fever ticks and Texas fever plundered the people of the United States of $73,000,000 annually. He also pointed out that the total federal and state expenditures for eradication work up to date aggregated $41,679,520, so that the total cost of this work so far is less than the loss sustained *in one year* as a result of the depredations of the ticks and Texas fever.

While the Texas fever tick is alone responsible for the transmission of Texas fever in the Americas, there are other species capable of spreading this disease in other parts of the world. For instance, a subspecies of the Texas fever tick is found in Australia which is capable of transmitting the disease, namely, *Boophilus annulatus, australis.* Curiously enough, a recent check-up has revealed the fact that this particular subspecies is also found in Florida and Texas.

The castor bean tick (*Ixodes ricinus*) is responsible for the transmission of a disease similar to Texas fever in various parts of Europe, while in South Africa the blue tick (*Boophilus decoloratus*) is the vector.

Now that Texas fever has been largely eradicated in the United States, another disease of cattle has sprung up to take its place, namely, anaplasmosis. This disease is caused by an organism so similar to that causing Texas fever that it is only within comparatively recent times that the difference has been realized. Anaplasmosis does not depend on the Texas fever tick for its transmission, as three ticks so far are known to be capable of carrying it. These three are: the dog-tick (*Dermacentor variabilis*), the brown dog-tick (*Rhipacephalus sanguineus*) and the wood-tick (*Dermacentor andersoni*). There is a possibility that other arthropods may be involved in the transmission of anaplasmosis, in which case the disease will be a difficult one to control. Already it is spreading and is causing heavy losses in some of the southern and central states.

The list of ticks responsible for the spread of diseases in animals by means of the piroplasma group of organisms is so great that the reader's patience would be exhausted if an attempt were made to go into detail. However, it might be of interest to state briefly that biliary fever in horses and mules in South Africa and equine piroplasmosis in the same animals in Russia are transmitted by ticks, while East African coast fever in cattle, ictero-hematuria or heart-water disease in sheep and malignant jaundice in dogs are also caused by species of piroplasmas transmissible by various species of ticks.

Tularemia or deer-fly fever is another tick-borne disease which has been given considerable publicity in the press, chiefly because it affects wild rabbits and is easily transmitted to those who handle or dress these animals, such as hunters, butchers, housewives, etc. Tularemia produces in human patients such symptoms as a papule and inflammation at the point of infection, fever, chills, painful swelling of the lymphatic glands, general malaise, etc. The mortality rate in humans is not high, but thousands of rabbits die as a result of the infection. Some biologists are of the opinion that tularemia is a factor of great importance in "weeding out" the rabbit population when it becomes too numerous. Wild rabbits are therefore to be regarded as natural reservoirs of infection. Many other animal hosts, such as rats, field mice, sheep, muskrats, opossums, woodchucks, cats and game birds, are also recognized as reservoirs of infection.

The principal vector of tularemia seems to be the deer-fly (*Chrysops*). The wood-tick (*Dermacentor andersoni*), the rabbit tick (*Haemaphysalis leporis*

palustris) and the rabbit louse (*Haemodipsus ventricosus*) are also known to be carriers of infection.

While the deer-fly is one of the principal spreaders, the infective agent remains alive in its body for only a few days, whereas in the body of the wood-tick it remains alive throughout the life of this parasite.

Poultry raisers have also reason to fear ticks, because there are several species capable of causing considerable damage to chickens and other domestic fowls. For instance, the fowl-tick (*Argas miniatus*), commonly called the "blue bug," is such a pest in the south-western states that poultry raisers have to wage a constant fight in order to keep it under control.

The fowl-tick, besides doing considerable damage to poultry by its blood-sucking propensities, also transmits fowl spirochetosis—a disease caused by a blood spirochete (*Spirocheta gallinarium*), first recognized in Brazil. It also affects poultry in other parts of South and Central America, Africa, Europe, and possibly in some of the southern states of North America. Spirochetosis is most common among chickens, but it is also found in geese, ducks, pigeons and sparrows. In Persia and Tunis the same disease is transmitted by a fowl-tick of the same genus as the above, namely, *Argus persicus*.

In addition to their blood-sucking habits and their ability to act as vectors of disease, ticks (at least some species) have a third undesirable quality—they are capable of causing a peculiar type of paralysis which is thought to be due to the injection of toxins into their victims at the time of feeding. Paralysis attributed to ticks has been reported in humans, dogs, horses, sheep, pigs, rabbits, foxes, moose and cattle. Definite proof that tick paralysis is caused by toxins secreted by the salivary glands of ticks and not by pathogenic organisms or virus is afforded by the fact that as soon as the ticks are removed from the body the patient makes a rapid recovery. So far as known, only female ticks cause paralysis. The tick chiefly responsible for paralysis in man and animals in the United States is the versatile wood-tick (*Dermacentor andersoni*). In Australia a dog-tick (*Ixodes holocyclus*) causes paralysis in dogs, poultry, pigs and other animals. There are no doubt a number of species of ticks capable of causing paralysis about which little or nothing is known at present.

While it has been generally accepted that tick paralysis is caused by a toxin secreted by ticks, the work of Wallace, Cahn and Thomas (1933) on "Moose Disease" is worthy of serious consideration. These investigators found that a disease of wild moose, resulting in paralysis of the limbs and usually in death, was apparently produced by a bacillus, *Klebsiella paralytica*. This organism was isolated from ticks (*Dermacentor albipictus*) that had fed on infected moose, and when cultures of it were injected into guinea pigs, rabbits, chickens, lambs and an Ayrshire bull, they produced symptoms which were practically identical with those seen in moose disease. It would therefore seem that the cause of tick paralysis is open to further investigation.

Acarina (mites): Several species of mites barely visible to the unaided eye burrow into the skin or other tissues of the bodies of domestic animals, causing considerable expense and exasperation to owners and being a source of great discomfort and ill health to their victims. The condition produced by mites is generally called mange by the laity and scabies by veterinarians. These names are derived from the fact that the burrowing habits of mites cause an outpouring of serum that coagulates or

dries on the surface of the skin, producing a thick, hard crust. In the case of scabies caused by sarcoptic, psoroptic and chorioptic mites, considerable irritation is produced which causes the affected animals to constantly rub themselves against convenient objects in order to allay the itching, thereby helping to spread the mites to other susceptible animals.

All these types of mange respond rather readily to appropriate treatment and proper sanitary regulations.

There is another species of mite, however, that is the despair of dog-owners and veterinarians alike. It is called the "follicular mite" (*Demodex folliculorum*). This mite invades the hair follicles and is very difficult to reach with parasiticides on account of its deep-seated and protected position at the base of the hair roots. So difficult is follicular mange to cure when well advanced that nothing short of heroic and persistent treatment can conquer it.

Another type of mange mite invades the ears of dogs, foxes, cats and rabbits, producing a scabby condition inside the ear which usually goes by the name of "canker"—a very inappropriate term, for canker may be due to other causes. The species of mites causing ear mange in dogs, cats and foxes is *Otodectes cynotis*. It causes a pronounced itching, so that the infested animals constantly scratch at their ears—which does not make matters any better. Bacterial complications may develop, with resulting inflammation of the middle ear, and possibly fits or convulsions and other disturbances which are very alarming to the owner and dangerous to the patient.

Another species of ear mite attacks the middle ear of domestic rabbits, namely, *Glyciphagus domesticus*. The condition produced by this mite is generally called "wry neck" by rabbit-breeders because the affected animals hold their heads on one side. In severe cases, rabbits are not able to stand up, and may die as a result of their inability to eat. This particular mite occurs only accidentally in the ears of rabbits. It is normally found in hay, straw and similar material.

In poultry there are several species of mites that cause serious pathological conditions; for instance, the common chicken mite (*Dermanyssus gallinae*) feeds on the blood of chickens during the night and hides in cracks and crevices during the day. This mite is one of the most serious pests the poultry raiser has to contend with. Quite recently another mite, *Liponyssus silviarum*, somewhat similar in morphology to the common chicken mite, has been introduced into the United States. This particular mite may become even more annoying to both chickens and their owners because it has entirely different habits. For instance, instead of feeding on the birds at night only, it remains on them all the time, even breeding among the feathers.

The scaly leg mite (*Cnemidocoptes mutans*) and the depluming mite (*Cnemidocoptes gallinae*) are two other mites which help to keep chickens entertained. The first produces a thick, scabby condition on the scaly portion of the legs, which is generally referred to by chicken raisers as scaly-leg. The depluming mite, as its name indicates, causes loss of feathers—the birds pulling out their feathers to ease the irritation produced by the mites. So badly denuded do some birds become that one might think they had started an avian nudist colony.

A discussion of mites would hardly be complete without reference to our old friend "the chigger" (*Trombicula irritans*), alias red bug, alias harvest mite, etc. Personally the writer does not

think the specific name of "irritans" is at all inappropriate; and he believes that any one who has been exposed to these pests will agree with him. Chiggers are one of the biggest curses of certain sections of the country, and one of the principal reasons why naturalists and other lovers of outdoors may, in spite of their enthusiasm, "quit the job" until the chigger season is over, unless they happen to have caught on to Dr. Ewing's prophylactic treatment in the form of liberal applications of sulfur to the lower parts of the body before going into chigger-infested territory.

Man is not the only animal attacked by chiggers; wild and domestic animals are seriously annoyed by them; in fact, chiggers often cause a high rate of mortality in young chickens continuously exposed to their attacks. Chiggers attack only in their larval form. The adults, according to Dr. Ewing, live largely on the fecal matter of arthropods and in decaying woody substances.

Chiggers in this country are not known to transmit disease, but the larvae of a Japanese species (*T. akamushi*) are responsible for the transmission of river-fever or "tsutsugamushi"—a highly fatal disease of man. The adults of this species of chigger live in the ears of field mice.

If the reader's patience has carried him to this point he will readily admit that insects and other arthropods are often of as much concern to the live-stock raiser as "overproduction" and failing markets for his product. It is rather strange that, while man has just about brought under subjection and control almost all the arthropods which cause him individual annoyance and sickness, he has done comparatively little to control or eradicate the legion of arthropod pests and vectors of disease which make the lives of domestic animals so miserable. As Dr. Maurice C. Hall has said, "man's chief concern seems to be to attack and destroy parasites which affect him personally," which perhaps accounts for the slowness with which he tackles the problem of controlling parasites of live stock. However, a tremendous amount of work has been done in the last few years in this direction, and it is the hope of the writer that this article may contribute, however slightly, to further interest in the control and eradication of the arthropod and other parasites of our benefactors and friends —the domestic animals.

THE EFFECT OF X-RAYS ON TISSUE REGENERATION

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Ever since the operator of one of the first x-ray tubes suffered the first x-ray burn it has been recognized that x-radiation is capable of exerting a profound effect on living tissue. Experimenters have found, however, that not all cells of an organism are equally sensitive to x-rays. Certain cells may be destroyed or may be rendered inactive by a dosage of x-rays which leaves other cells of the same organism apparently unharmed. It has been discovered that, in general, rapidly growing tissues are most susceptible to x-rays; tissues which are not undergoing rapid growth changes are less susceptible. This variability in the reaction of cells and tissues to x-rays places in the hands of the biologist an unusually efficient instrument of research, an instrument with which he is able to render certain cells inactive and by so doing discover the importance of these cells to the organism as a whole. X-rays, for example, have been found particularly useful in the investigation of certain problems of tissue growth such as the problem of regeneration.

Many animals possess the ability of regenerating parts of the body which have been lost through injury. In the case of the common earthworm, for example, if one end of the worm be cut off then the portion of the body which remains is able to regenerate the lost part in approximately its original condition. Lobsters and other crustaceans can regenerate new claws to replace lost ones, fishes can regenerate fins, and amphibians such as the salamanders are able to regenerate new limbs and tails.

About thirty years ago C. R. Bardeen and F. H. Baetjer discovered that the small flatworm, Planaria, which under ordinary circumstances regenerates lost parts of the body very rapidly, loses its capacity to regenerate after it has been exposed to x-rays. More recently it has been found, through studies by W. C. Curtis, that the failure of Planaria to regenerate after exposure to x-rays is due to the fact that the x-rays destroy certain cells in the body of the worm called formative cells. Since these formative cells normally are the source of the new tissue which is formed during regeneration, their destruction renders the Planaria incapable of regenerating. Much the same situation prevails in some of the segmented worms in which, as R. G. Stone has shown, specialized regeneration cells are destroyed by x-rays.

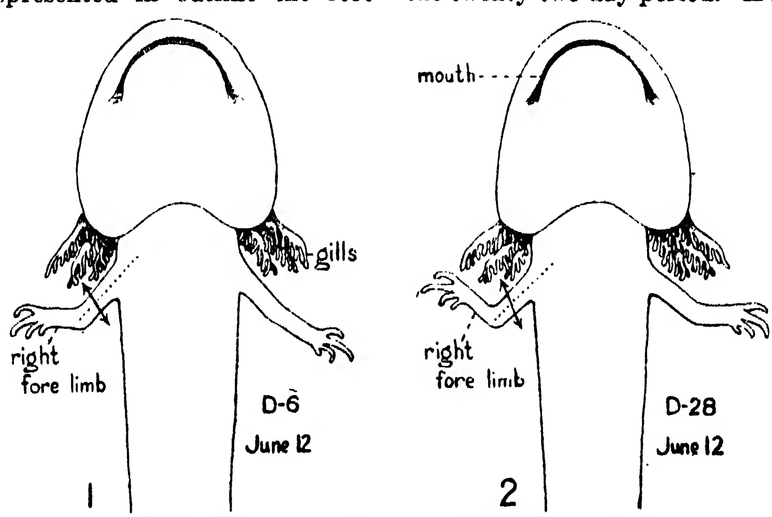
In the vertebrate animals no specialized regeneration cells, such as formative cells, have been found. However, a salamander which ordinarily can readily regenerate a lost limb, loses this ability after exposure to x-rays. This fact has been repeatedly demonstrated by experiments carried out in my laboratory in which the common American salamander (*Amblystoma punctatum*) was used. For experimental studies on regeneration the limb of this animal is a convenient structure, for the reason that under ordinary conditions it is very readily regenerated and in a young salamander regeneration of the limb takes place at a rapid rate. Within the space of three or four weeks, for example, a young salamander is able to regenerate an entirely new limb, the

length of time required depending to a large extent on the age of the animal. Younger salamanders regenerate more rapidly than older ones. However, if a salamander which possesses this remarkable capacity for regeneration be given a single exposure to x-rays in proper dosage, then this capacity is completely lost.

It has been found that the age of the animal used does not modify the effect of x-rays on limb regeneration. Regeneration is prevented as readily in an animal which possesses a fully developed limb as in a young larva in which the limb is just developing. The age of the animal or the stage of limb development, therefore, is not a factor. A salamander of any age when exposed to x-rays in proper dosage loses completely its ability to regenerate a ne'v limb.

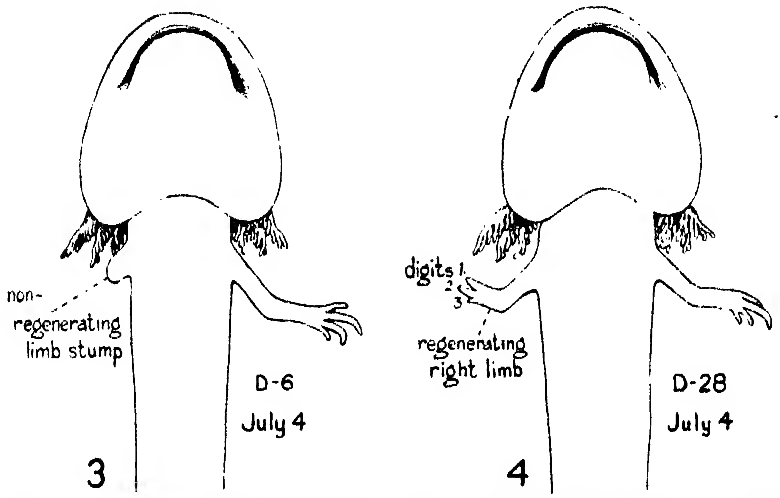
The description of a simple experiment will serve to demonstrate how readily observable are the effects of x-rays on regeneration. In Figs. 1 and 2 are represented in outline the fore part of the body of two young salamanders as seen from the under side. Each hand or fore foot has four digits, which is the full number of digits for the fore limb of this species of salamander. On June 12 the right fore limb of each salamander was amputated through the middle of the upper arm at a point indicated by the double pointed arrow. After the amputation the salamander shown in Fig. 1 was given a dosage of x-rays. The other salamander, shown in Fig. 2, was not x-rayed and was left to develop normally.

In Figs. 2 and 3 are represented the same two salamanders twenty-two days after the amputation of the right fore limbs. The x-rayed individual, represented in Fig. 3, shows a total absence of regeneration. The wound of amputation has healed, but no regeneration of a new limb has taken place. Fig. 4, representing the normal unradiated salamander, demonstrates the amount of regeneration which has taken place during the twenty-two day period. A new right



FIGS. 1 and 2. AMPUTATION OF THE LIMBS

THE DRAWINGS SHOW TWO YOUNG SALAMANDERS. THE DOUBLE POINTED ARROW ACROSS EACH RIGHT FORE LIMB INDICATES THE POINT AT WHICH THE LIMB WAS AMPUTATED ON JUNE 12. AFTER THE AMPUTATION THE SALAMANDER SHOWN IN FIG. 1 WAS EXPOSED TO X-RAYS. (THE DRAWINGS WERE MADE WITH THE ANIMALS LYING ON THEIR BACKS. IN EACH CASE ONLY THE FORE PART OF THE BODY IS SHOWN.)



FIGS. 3 and 4. REGENERATING AND NON-REGENERATING LIMBS
THE SAME SALAMANDERS SHOWN IN FIGS. 1 AND 2. THESE DRAWINGS WERE MADE 22 DAYS AFTER THE AMPUTATION OF THE RIGHT FORE LIMB OF EACH ANIMAL. NO REGENERATION HAS TAKEN PLACE IN THE X-RAYED SALAMANDER, FIG. 3. THE RIGHT FORE LIMB OF THE NORMAL UNRADIATED SALAMANDER, FIG. 4, IS REGENERATING NICELY.

limb has already regenerated as far as the three-digit condition. A few days after this drawing was made the fourth digit appeared, and soon the right limb was again in the same condition as the unharmed left limb.

In other experiments young salamander larvae in which the fore limb is just beginning to develop have been used. For example, one may amputate the limb bud at a time when it has just appeared on a young salamander larva as a small blunt protrusion or bud on the side of the body wall. Such an early stage of limb development is shown on the larva represented in side view in Fig. 5. Amputation at this early time consists simply in clipping off the free end of the little limb bud. The wound heals very quickly in a young larva, such as this, and, under normal conditions, regeneration of the limb bud and subsequent normal limb development takes place at a rapid rate. However, if after the amputation of the small limb bud the larva be exposed to x-rays, then the limb will fail to develop. This experiment shows that even in this young stage of development x-radiation has completely removed from the animal the capacity for limb regeneration.

Since x-radiation exerts so pronounced an effect on the regeneration of limbs, it is not surprising to disoover that the normal development of limbs in young salamanders is also subject to modification by x-rays. Recently W. O. Puckett, working in the Princeton laboratory, has made a detailed study of the influence of x-rays on normal limb development. His work shows that exposure to x-rays at the proper time will completely suppress normal limb development. This effect may be readily demonstrated by the following simple experiment on hind limb development. Hind limbs in the salamanders used for these studies normally develop much later than fore limbs. It will be noticed in the salamander larva shown in Fig. 5, for example, that although fore limbs are starting to develop, there is no sign

of hind limbs. In fact, the fore limbs will be well along in development before the hind limbs put in their appearance. Now, if such a larva as shown in Fig. 5 be exposed to x-rays, then hind limbs will never appear at all. The salamander will develop into an individual which remains entirely limbless in the posterior part of the body.

Not only is it possible to suppress totally the development of limbs, but also one can suppress the development of parts of limbs. Consider, for example, the formation of the digits on the fore limb. Normally digits numbers 1 and 2 are the first to develop. They arise through the formation of two little outgrowths at the tip of the originally blunt limb bud. Then digit number 3 appears as a little outgrowth near the base of digit 2, as one sees it developing on the right limb of the animal in Fig. 4. Finally, at a still later time digit number 4 develops as a small outgrowth near the base of digit 3. In this manner the adult hand or fore foot is built up. Now, when one exposes to x-rays a young salamander larva with fore limbs on which only the first two digits have been formed, then the formation of the third and fourth digits will be prevented; each fore limb will remain as a permanent two-digit limb. Likewise, if one waits till a little later and radiates a salamander at a time when the first three digits have been formed, then the formation of the fourth digit will be suppressed, and the limb will remain

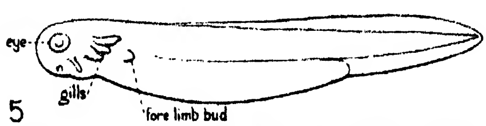


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FIG. 5. YOUNG SALAMANDER LARVA. (SIDE VIEW.)

THIS LARVA SHOWS AN EARLY STAGE IN THE DEVELOPMENT OF THE FORE LIMB, WHICH APPEARS AS A SMALL BUD GROWING OUT FROM THE SIDE OF THE BODY. THE HIND LIMB BUDS HAVE NOT YET APPEARED.

as a permanent three-digit limb. Moreover, as we have learned from earlier experiments, if at any time one of these permanent two-digit or three-digit limbs be amputated it will fail to regenerate. The exposure to x-rays which prevented digit development also removed the capacity for any future regeneration of the limb.

With these facts in mind, it will be seen that through the proper use of x-rays salamanders with almost any type of limb desired can be produced. For example, by radiating at a time when fore limbs have been formed, but hind limbs have not yet appeared, one can obtain an animal which possesses well-developed fore limbs, but no hind limbs at all. Also, by proper correlation of radiation and amputation it is possible to obtain a salamander, which, let us say, has one fore limb in a permanent two-digit condition and the other fore limb in a permanent three-digit condition. Indeed, by radiation at the proper time limbs with any desired combination of digits, within the limit of four, can be secured.

Thus far we have been considering experiments in which the entire salamander was subjected to the influence of the x-rays. Other experiments have been made in which a portion of the animal has been shielded with pieces of lead plates which are impervious to x-rays. By this method it is possible to subject only a certain definite part of the body to the x-rays. For example, by shielding the region of the hind limbs and radiating only the fore part of the body one renders the fore limbs incapable of regenerating, while the hind limbs retain their full potentialities. In this manner an animal which possesses hind limbs, but is without fore limbs, can be produced. Or, one may shield the right half of a salamander and leave the left half exposed to x-rays. Under these circumstances, both the fore and

hind limbs on the left side lose their capacity for regenerating, while the fore and hind limbs on the right side remain normal. These experiments demonstrate, among other things, that the effect of x-rays on limb regeneration is a local effect. In other words, it is an effect which the x-rays exert directly on the cells in the limb area, and is not a general effect on the animal as a whole.

Interesting as are the foregoing experiments, it is of still further interest and importance to inquire into the alterations which take place within the limbs of x-rayed salamanders. What changes have the x-rays brought about in the tissue, so that it is no longer capable of regenerating? In order better to understand the changes which take place within the non-regenerating limbs of x-rayed salamanders, let us examine first the manner in which new tissue is formed during normal regeneration of the salamander limb.

In Fig. 6 are shown three photographs of normally regenerating limbs eighteen hours, eight days and twelve days after the amputation of the limbs. Each photograph was made from a thin section which was cut lengthwise through the limb in the plane indicated by the dotted line along the right limb in Fig. 2. All three photographs are highly magnified. By a study of these sections one may follow the tissue changes taking place during regeneration.

The upper photograph in Fig. 6 shows a section through the stump of an amputated limb eighteen hours after the amputation. In the section are shown the scapula or shoulder blade and the humerus or bone of the upper arm which has been amputated about midway between the shoulder and the elbow. (In the young salamanders used for this experiment the humerus was made up of cartilage instead of bone, which develops later.) Healing of the wound of amputation has already taken place during the first eighteen hours. It consists, as shown in the photograph, in the growth over the raw stump of the surrounding skin or epidermis. During healing the epidermis becomes slightly thickened at the end of the limb, as the photograph shows.

The middle photograph in Fig. 6 shows the beginning of actual regeneration. Many alterations are now taking place among the cells of the limb stump which will result finally in the regeneration of a new limb. The first important change, and the one which is the signal for the building up of a new limb, is the appearance of a group of cells between the cut end of the humerus and the tip of the limb. These cells, well shown in the middle photograph in Fig. 6, make up what is known as the regeneration blastema. The cells of the blastema are of great importance, for it is from these cells that all the components of the new limb, except the nerves, will be formed. Once it has appeared, the regeneration blastema enlarges rapidly in size, and soon some of the cells of the blastema line up in rows preparatory to the formation of new cartilage at the cut end of the old cartilage stump. From then on regeneration of the limb goes on rapidly.

The lower photograph in Fig. 6 shows clearly the formation of new tissue, particularly cartilage, in a regenerating salamander limb twelve days after amputation. The new humerus is plainly mapped out as far down as the elbow. One can clearly see, however, where new cartilage joins on to the old cartilage. This point of junction indicates the place where the limb was amputated twelve days before. The formation of a new lower arm is also progressing rapidly. Already a little notch at the tip end of the limb indicates the formation of the first two digits. Soon the third digit and then the fourth will appear. Within a month after the original limb was amputated a new limb will have been completely regenerated.

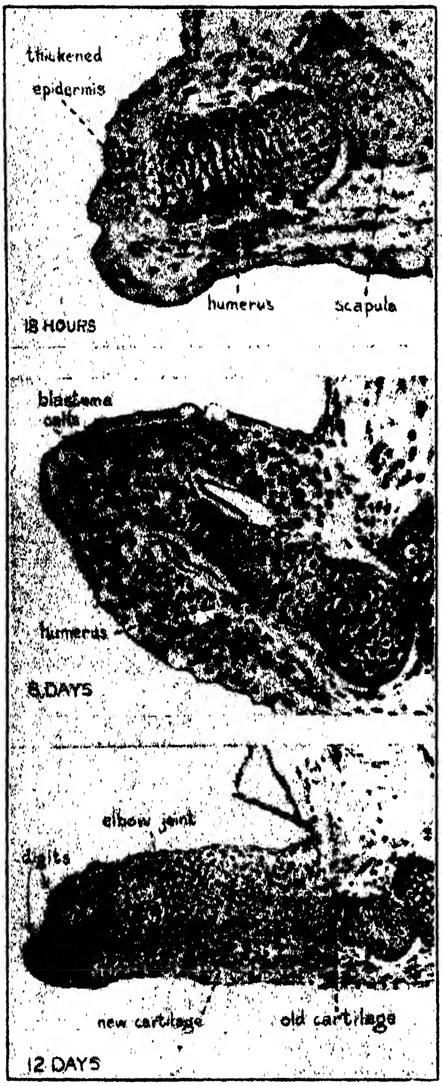


FIG. 6. REGENERATING LIMBS

THE PHOTOGRAPHS SHOW CHANGES WHICH TAKE PLACE WITHIN THE TISSUE OF THE SALAMANDER LIMB DURING NORMAL REGENERATION. EACH PHOTOGRAPH WAS MADE FROM A THIN SECTION CUT LENGTHWISE THROUGH THE LIMB IN THE PLANE INDICATED BY THE DOTTED LINE ALONG THE RIGHT LIMB IN FIG. 2. (ALL PHOTOGRAPHS ARE HIGHLY MAGNIFIED). THE UPPER PHOTOGRAPH SHOWS A LIMB STUMP 18 HOURS AFTER LIMB AMPUTATION. THE MIDDLE PHOTOGRAPH IS A REGENERATING LIMB 8 DAYS AFTER AMPUTATION. THE LOWER SHOWS REGENERATION PROGRESSING RAPIDLY 12 DAYS AFTER LIMB AMPUTATION.

Having in mind, now, the main tissue changes which take place during the normal course of regeneration, let us turn to a study of the conditions which one finds in the tissue of the non-regenerating limb stumps of x-rayed salamanders. What alterations in the tissue have the x-rays brought about which render the limb incapable of regenerating?

When one studies the changes taking place within the limb stump of an x-rayed salamander, such as the animal shown in Figs. 1 and 3, for example, one finds that they are strikingly different from those which accompany normal regeneration. However, differences in the tissue of radiated and unradiated animals do not become apparent immediately after amputation. During the first few days no very pronounced changes occur within the amputated limb other than the healing of the wound, which ordinarily takes place in an x-rayed salamander as rapidly as in a normal unradiated individual. On about the sixth day after amputation the similarity between the radiated and the unradiated animals ceases, and changes of an extraordinary and far-reaching nature begin within the limb stumps of the x-rayed salamanders. These changes are associated, first, with the region of the limb which normally is occupied by the cells of the new blastema, referred to above, and secondly, with the cartilage of the humerus.

In Fig. 7 are shown photographs of sections through the limb stumps of x-rayed salamanders six, eight and eighteen days after limb amputation. As before, these are photographs of thin sections cut lengthwise through the limbs in the plane indicated by the dotted line along the right limb in Fig. 1. A study of these sections reveals the differences between the tissue of non-regenerating limbs of x-rayed salamanders and the tissue found in normally regenerating limbs.

The upper photograph in Fig. 7 shows a section through a limb stump of an x-rayed salamander six days after the limb was amputated. One notices at once the absence of a regeneration blastema at the tip end of the limb, as was seen in normal regeneration. One observes, also, that the cartilage of the humerus is undergoing a striking change. These two are the most pronounced changes which are brought about by the x-rays. No regeneration blastema ever forms in the limb of an x-rayed salamander, and the old cartilage of the humerus, as time goes on, gradually degenerates and disappears.

The extent to which the cartilage dissolution or degeneration takes place in the limbs of radiated salamanders is startling. Eight days after the amputation all the humerus of the limb has dissolved and disappeared, except the upper end or head. Such a condition as this is shown in the middle photograph in Fig. 7. The dissimilarity between radiated salamanders and normal salamanders can readily be seen by comparing the middle photographs of Figs. 6 and 7. In the normal animal, Fig. 6, the rebuilding of the limb from the new regeneration blastema is just about to begin. In the radiated animal, Fig. 7, there is no regeneration blastema and no sign of rebuilding, but, on the contrary, an extensive degeneration of tissue has set in.

In the lower photograph in Fig. 7 is seen a non-regenerating limb stump of an x-rayed salamander eighteen days after the amputation of the limb. All tissues within the limb have now undergone degeneration. Not only has the humerus degenerated and disappeared entirely, but the scapula or shoulder blade is also gone. Such a limb as this can never regenerate, but will simply remain as a little stump on the side of the body. The capacity for regeneration has been entirely lost.

But is there no way at all, one may

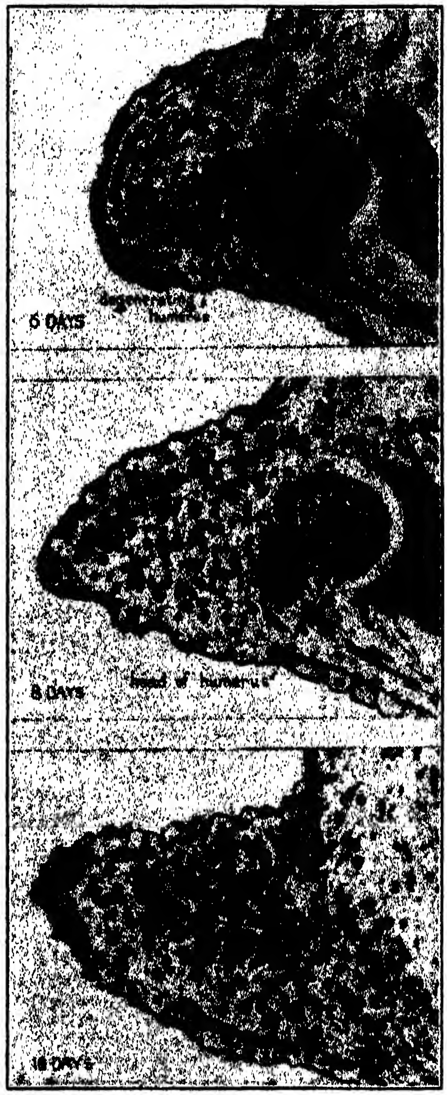


FIG. 7. NON-REGENERATING LIMBS

THE PHOTOGRAPHS SHOW CHANGES WITHIN THE TISSUE OF NON-REGENERATING LIMB STUMPS OF X-RAYED SALAMANDERS. COMPARE THESE SECTIONS WITH THOSE THROUGH REGENERATING LIMBS SHOWN IN FIG. 6. (THESE SECTIONS HAVE BEEN CUT IN THE SAME MANNER AS THOSE IN FIG. 6.) UPPER: NON-REGENERATING LIMB STUMP SIX DAYS AFTER LIMB AMPUTATION. MIDDLE: NON-REGENERATING LIMB EIGHT DAYS AFTER AMPUTATION. LOWER: DEGENERATION OF TISSUE IN A NON-REGENERATING LIMB STUMP EIGHTEEN DAYS AFTER LIMB AMPUTATION.

ask, by which an x-rayed salamander may regain the ability to regenerate a limb? Can not the animal in some manner be rehabilitated? The ability to regenerate can be restored only when a radiated animal is supplied with a new unradiated limb. This can be done by removing from a normal unradiated salamander a limb, and transplanting it to the body of an x-rayed individual. The transplanted limb may be placed in the normal limb location where it will grow, and often the salamander is able to use it in getting about nearly as well as it used its original limb. Now, if such a transplanted limb as this be amputated, then a new one will be regenerated. In this manner has the regenerative ability been restored to the x-rayed animal.

From a comparison, therefore, of the regenerative capacities of normal and x-rayed salamanders several conclusions are obvious. We find that when the formation of a new blastema is suppressed through the use of x-rays, then regeneration is prevented. We learn, moreover, that the cells which normally make up the regeneration blastema, and thereby enter into the formation of the new limb, come from the region of the limb itself and not from distant parts of the body, as some biologists have heretofore thought. The transplantation experiments just mentioned prove this point conclusively. We find, also, that in an x-rayed salamander the opposite of regeneration, namely, degeneration, takes place. It appears as though when tissues of the limb are prevented from regenerating, they must of necessity degenerate. There are reasons for thinking that the extensive degeneration of the humerus in x-rayed salamanders, for example, is due to the absence of a regeneration blastema.

Experiment, when applied to a study of developmental processes, invariably brings about the formation of abnormal animals. It is through a careful analysis of these abnormal individuals that the experimentalist gains new insight into the factors which underlie normal development. In x-rays the biologist has an efficient instrument of research, a new method for experimental analysis.

JOHN WESLEY POWELL
1834-1902[1]

By Dr. WILLIAM HERBERT HOBBS
PROFESSOR EMERITUS OF GEOLOGY, UNIVERSITY OF MICHIGAN

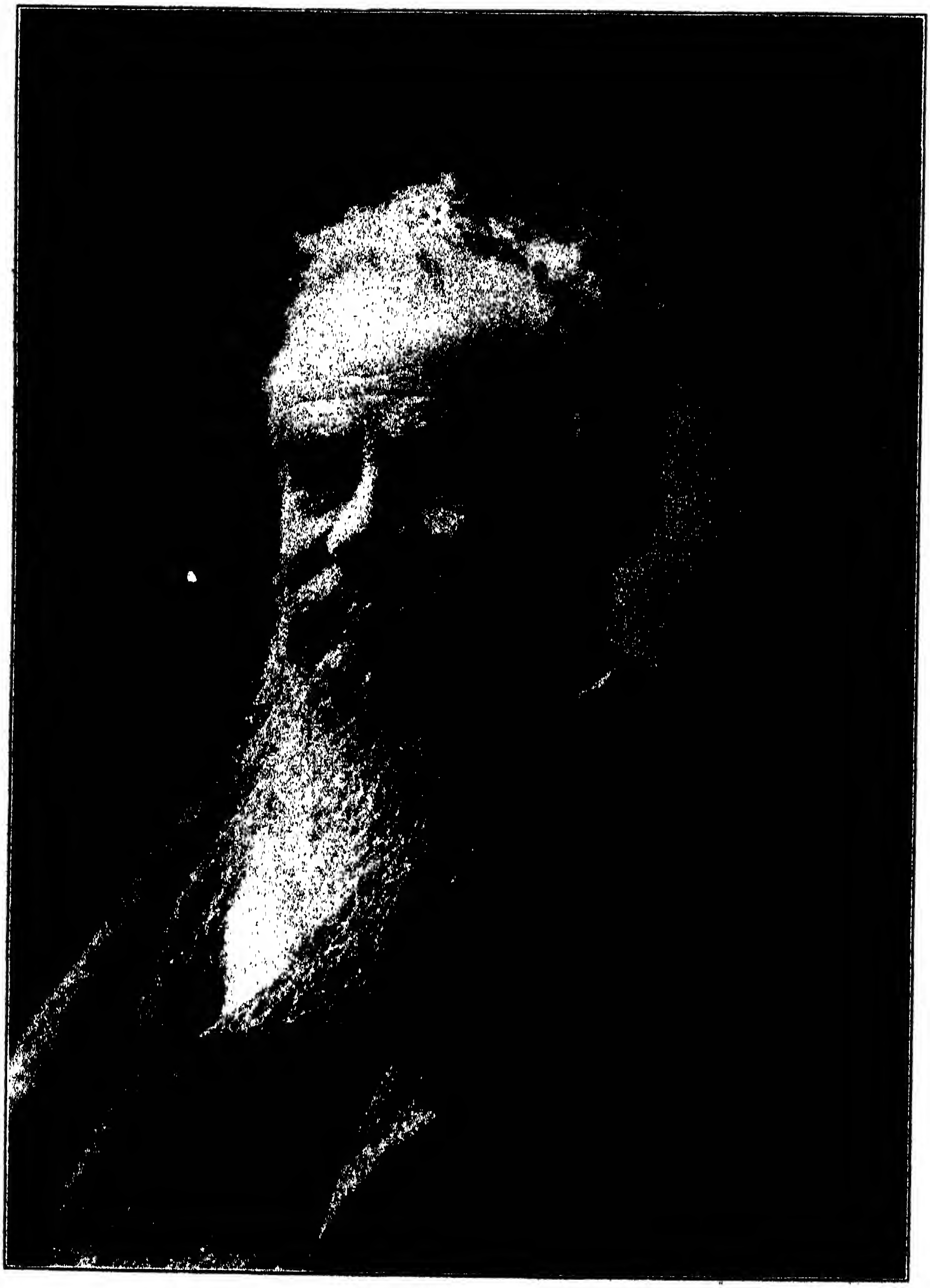
John Wesley Powell's many-sided career was an expression of that remarkable period which was opened by the American Civil War and followed by the development of the Great West. It was first as soldier, then as teacher, then explorer, later as geologist, anthropologist and philosopher; but perhaps more than all as the creative administrator who initiated and shaped the policies of some of our great scientific bureaus that his name will be long remembered. Powell was the father of the U. S. Geological Survey, of the Bureau of American Ethnology and of the vast Reclamation Service of the country. His life falls naturally into several distinct periods, each marked by a special line of endeavor.

John Wesley Powell was born on March 24, 1834, at Mount Morris in the State of New York. His father was a Methodist clergyman who had emigrated to America from England only a few years before. When Powell was seven years old his parents removed to Jackson, Ohio; five years later to South Grove in Walworth County, Wisconsin; five years later to Bonus Prairie, Boone County, in northern Illinois, and lastly to Wheaton, Illinois, where the Wesleyan College had just been established. During these peripatetic movements of the Methodist clergyman, the chief support of the family was a farm, which was left largely to the care of Powell as a mere boy, and he thus early learned the lesson of self-reliance and came into intimate communion with nature. Young Powell attended the country schools when he could, particularly at Janesville, Wisconsin, and later Wheaton and Illinois colleges irregularly, earning for a part of the time his support by service nights and mornings, by teaching and by lecturing on natural history. The only account of these lectures which has survived in print is one delivered at Ann Arbor, and for the reason that Powell was ragged by the students there because he wore a coat with long tails. His clever retort brought him instant applause. Later he had two years of work at Oberlin College, where he specialized in natural history. In 1859 he was elected to the secretaryship of the Illinois Natural History Society.

In the spring of 1860 Powell visited the southern states on a lecture tour and gained the clear impression that a civil war was inevitable. In the following summer he became principal of the public schools of Hennepin, Illinois, which with great vigor he organized and graded, keeping up, however, his natural history collections.

Powell's southern lecture tour had convinced him that a war between the sections was inevitable, and in the winter of 1860–1861 he took up seriously the study of military tactics and engineering. When Lincoln issued his call for troops, he was the first in his community to enlist, and Company H of the 20th Illinois Regiment of Volunteers was raised largely through his efforts, though he enlisted as a private and went out as sergeant-major. At Cape Girardeau, Missouri, his knowledge of military engineering made him invaluable, and he was

[1] The author is much indebted to Mr. Frederick S. Dellenbaugh, artist of Powell's second canyon voyage, who has read critically the manuscript and supplied illustrations.



—*Bachrach*

PORTRAIT OF MAJOR POWELL IN LATER LIFE.

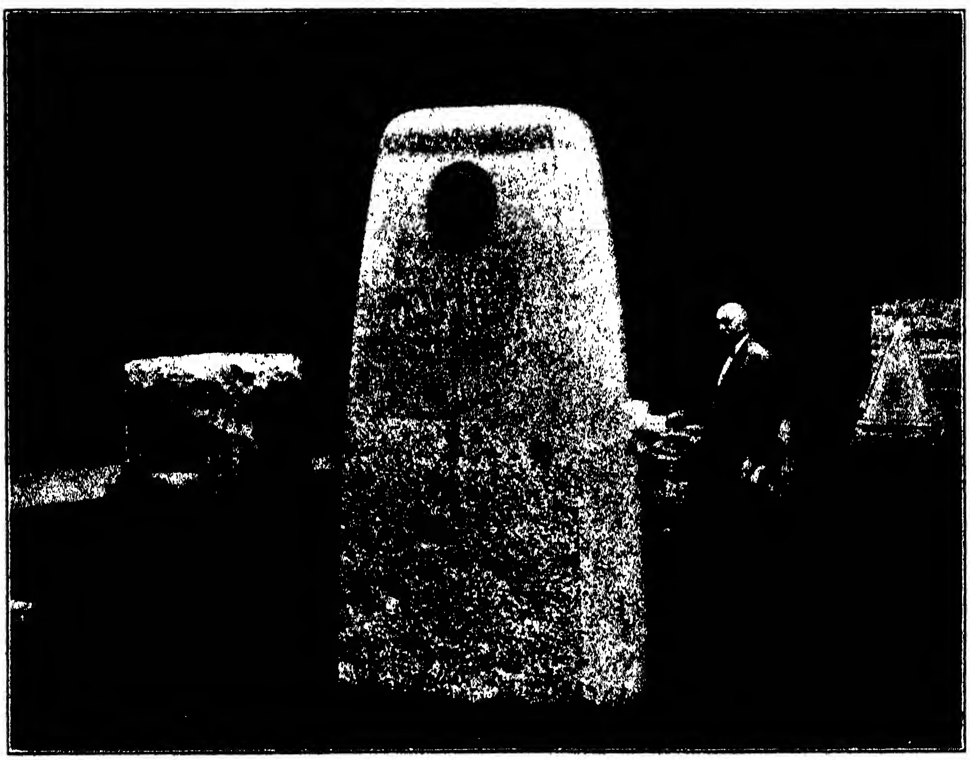
given practical charge of constructing the fortifications of the place. As a consequence he was highly commended by General Fremont, and he was promoted to second lieutenant. When the regiment was ordered away, he was left in charge of the fortifications he had so largely constructed. In the winter of 1861–1862 he recruited a company of artillery from the loyal Missourians, which company became Battery F, 2nd Illinois Artillery, with Powell as captain.

Ordered to Pittsburg Landing, Tennessee, at the battle of Shiloh a rifle ball carried away his hand. Clumsily dressed, a second operation was unskilfully made in the hospital which left a small stump only below the elbow. Throughout almost his entire life Powell was never for any long period free from racking pains in this arm, and it was a few years only before his death that a third and elaborate operation at the Johns Hopkins Hospital gave him relief.

As soon as the earlier wounds were healed, despite his lost hand, Powell went back into service and at the siege of Vicksburg was a division chief of artillery. He took part in the operations at Natchez and New Orleans. In 1864 he was assigned to the army of Tennessee under General Thomas, bringing with him twenty batteries of artillery. He served on General Thomas's staff until mustered out at the end of the war.

In 1862 Captain Powell was married to his cousin, Emma Dean, of Detroit, to whom he had long been engaged. A few hours later with his bride he was on his way back to the field, where she took up the work of a nurse.

When in January, 1865, Powell was



—*F. S. Dellenbaugh*

POWELL'S MONUMENT IN ARLINGTON NATIONAL CEMETERY FINISHED IN 1914. POWELL'S FRIEND, COLONEL H. C. RIZER, IN THE BACKGROUND

discharged from the army after a career conspicuous for achievement, he dropped all interest in military affairs as suddenly as he had entered upon them. Though he had held high command with rank of lieutenant-colonel it was as "the Major" that he was always affectionately referred to in after life.

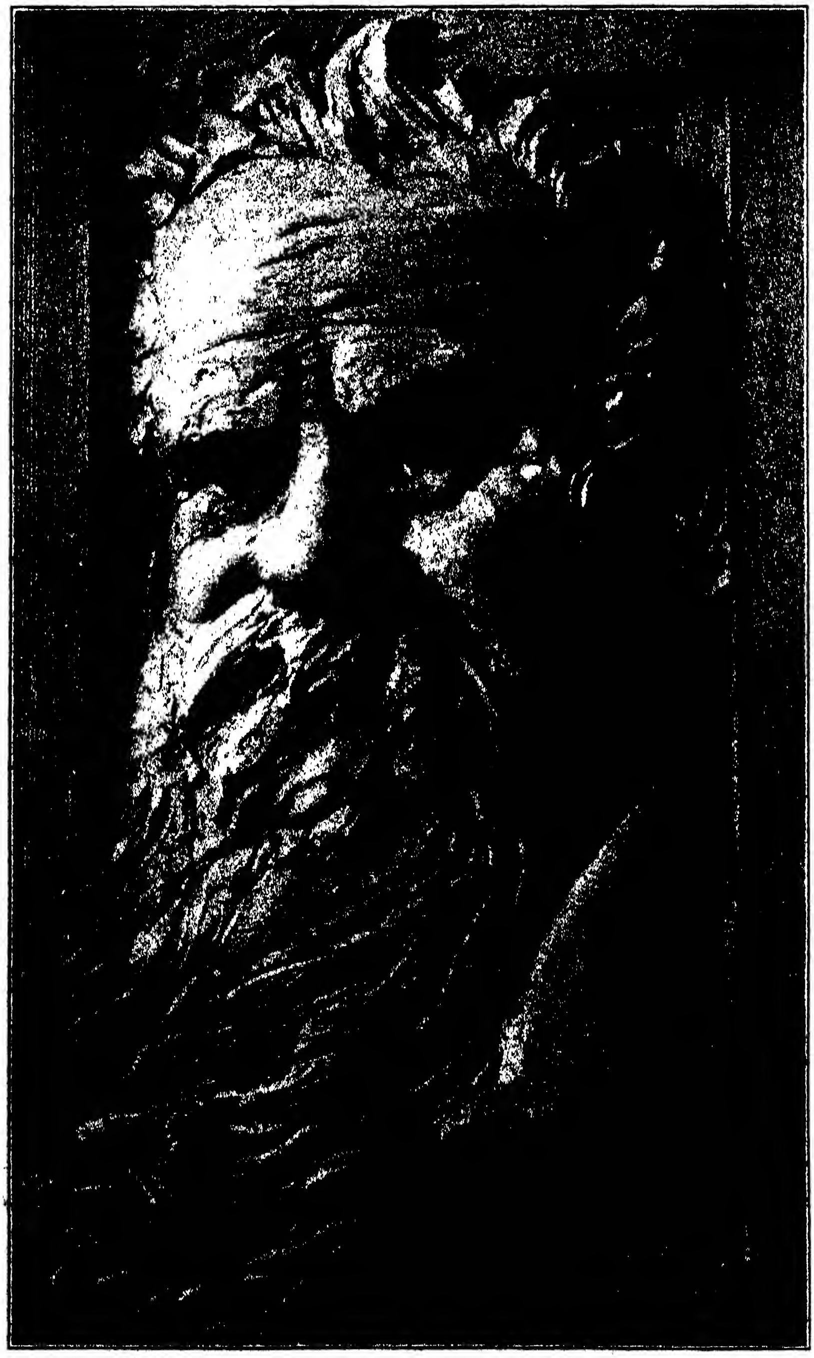
His career as a soldier concluded, Powell returned with great enthusiasm to his work as a naturalist and teacher. In 1865 he was made professor of geology and curator of the museum in Illinois Wesleyan University at Bloomington, but later he resigned to accept a similar position at Illinois Normal College. In 1867, with a class of sixteen students, he set out for the mountains of Colorado on what was the pioneer of extended geological field trips in America, and as that part of the country was not yet served by railroads, it was a somewhat arduous undertaking, but carried out with complete success. His faithful wife accompanied him on a similar trip in 1868 but with a larger party, and when the students returned, the Powells remained in the Rocky Mountains, wintering at White River in Wyoming, as he wished to continue his geological explorations.

This was the time that the idea to explore the Grand Canyon of the Colorado took firm hold upon him. Bold as this undertaking was, it was taken up in no spirit of adventure, but solely with a view to lift the veil from the scientific secrets hidden within the canyon's dark recesses. No one better than Powell appreciated the dangers to be faced. The Union Pacific Railroad had then just reached the crossing of the Green River in Wyoming. The Green was a tributary of the Colorado, and it was known that the waters fell 6,000 feet in the 1,000 miles before they reached the lowlands of the Southwest; and this to a certainty meant many rapids and falls. The country through which the river coursed was made up of high plateaus, within which the river was incised in steep-walled canyons from which it would in most places be exceedingly difficult, if not impossible, to climb out. Once launched upon the undertaking, there could be no turning back, and whatever the dangers, the only way to go was forward. After the winter spent in White River in Wyoming in careful exploratory work within the surrounding plateau country, Powell decided that, great as was the risk, the objects to be attained fully warranted the attempt to explore the canyons, and, as with Nansen, the results proved that his judgment was sound. Not a man was lost who remained with his leader.

In considering the audacity of this enterprise, it must not be forgotten that the leader had only the stump of his right arm, yet he always took his place as leader in the pioneer boat, and though repeatedly upset in swift rapids, with the aid of a life preserver he managed to make his way out by clinging with his one hand to the capsized boat. Many times the expedition missed complete disaster by the narrowest of margins, and once when about fifty miles from the end the rapids ahead were so terrifying and with no possibility of a portage that three members of the party refused to go on. These men succeeded in getting out of the canyon but were killed by the Shawits Indians on the plateau above. With his stauncher companions Powell succeeded in passing the first rapids safely, but all boats were swamped in a far worse falls farther down the canyon. However, they escaped safely, and shortly thereafter the boats ran out of the last of the granite into smooth water and the journey was at an end.

Powell has described this release from the canyon in some of the finest prose poetry in our language:

> The relief from danger and the joy of success are great. When he who has been chained by wounds to a hospital cot, . . . until the



RELIEF OF MAJOR POWELL ON WALL OF THE MUSEUMS BUILDING OF THE UNIVERSITY OF MICHIGAN, BY THE SCULPTOR CARLTON W. ANGELL OF ANN ARBOR

groans of those who lie about, tortured by probe and knife, are piled up, a weight of horror on his ears that he cannot throw off, cannot forget, . . . at last goes into the open field, what a world he sees! How beautiful the sky; how bright the sunshine; what "floods of delirious music" pour from the throats of birds; how sweet the fragrance of earth, and tree, and blossom! . . .

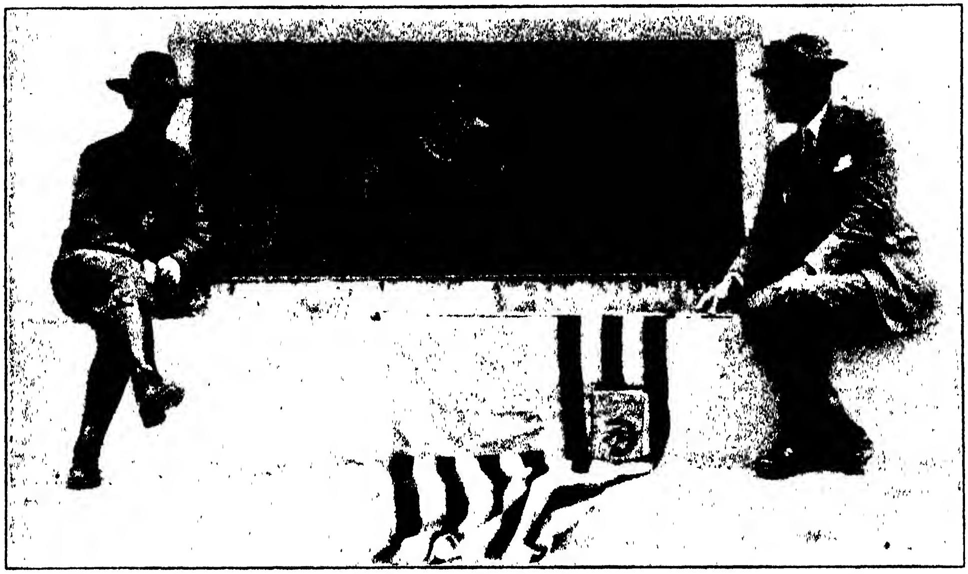
Something like this are the feelings we experience tonight. Ever before us has been an unknown danger, heavier than immediate peril. Every working hour passed in the Grand Canyon has been one of toil. We have watched with deep solicitude the steady disappearance of our scant supply of rations and from time to time have seen the river snatch a portion of the little left, while we were ahungered. . . . Only during the few hours of deep sleep, consequent on hard labor, has the roar of the waters been hushed. Now the danger is over; now the toil has ceased; now the gloom has disappeared; now the firmament is bounded only by the horizon; and what a vast expanse of constellations can be seen!

The river rolls by us in silent majesty; the quiet of the camp is sweet; our joy is almost ecstasy. We sit till long after midnight talking of the Grand Canyon, talking of home, but chiefly talking of the three men who left us. Are they wandering in those depths, unable to find a way out? Are they searching over the desert lands above for water? or are they nearing the settlements?

Owing to the defection of the three men it had been necessary to leave behind the geological specimens; and the hardships of the journey had made the traverse surveys uncertain and with important gaps. The leader was therefore unsatisfied with the results obtained and he determined to make another journey through the canyon. This time with government aid and a new party, a second canyon journey was carried out in 1871–1872 with many new perils, but now with complete success. Powell became a national hero, for the attention of the country had been focussed upon the expeditions and his first party had been reported lost. He thus became an earlier Lindbergh, and with equal modesty he shunned publicity. Nevertheless, in later years this position before the public was undoubtedly a great asset when it was necessary to secure appropriations from the Congress. Powell's interest, however, was wholly in the scientific results, and it was years before he published any narrative account, and then only when assured that he could expect no appropriations from Congress until his narrative was issued.

Powell's classic account of the Canyon journey is really a composite, a narrative of the first expedition with data inserted from the second. Nowhere would the reader suspect that the leader had lost an arm, though more than once he had been in serious trouble on this account, particularly when scaling the canyon walls for geological sections. Once when balanced precariously upon a narrow ledge high up on the canyon wall, he was forced to call for help. A companion higher up on the wall saw his predicament, but was without a rope. In desperation he divested himself of his underwear and lowered it from a shelf. Powell let go the rock just long enough to grasp with his one hand the improvised rope and was hauled to safety. Years afterward he wrote of his comrades on this expedition: "I was a maimed man; my right arm was gone; and these brave men, these good men, never forgot it. In every danger my safety was their first care, and in every working hour some kind service was rendered me and they transfigured my misfortune into a boon."

With the completion of the second Canyon journey, the second period of Powell's career, that of explorer, came to an end; and it is safe to say that no bolder expedition or one entered upon with higher motives or with more complete success has ever been undertaken in this country. In May, 1918, a memorial in the form of a stone altar supporting a bronze tablet with an account of Powell's expeditions was erected upon the brink of the Grand Canyon.



—*F. S. Dellenbaugh*

BRONZE TABLET ERECTED IN 1921

ON THE BRINK OF THE GRAND CANYON TO COMMEMORATE POWELL'S TWO VOYAGES. ON THE RIGHT IS F. S. DELLENBAUGH, ARTIST COMPANION OF POWELL ON HIS SECOND CANYON VOYAGE, AND ON THE LEFT EMERY KOLB WHO MADE A CANYON VOYAGE IN 1911. THE FLAG WAS CARRIED BY POWELL IN THE "EMMA DEAN" 1871–72.

Powell's studies within and about the Grand Canyon and within the Rocky Mountain Region continued for nine years and were made along three different lines—in geology, anthropology and reclamation, in each of which Powell was destined to become a foremost authority. The geological results of his labor are published in two quarto monographs as government publications, and in many shorter papers. The area covered is probably unsurpassed for the display on a large scale of geological structures, and the keen mind of Powell enabled him to lay the foundations of wholly new chapters in geological science. A new subscience of geomorphology or physiographical geology was born of his studies.

To cite Gilbert: "In connection with the field studies in these districts he developed a new classification of mountains, by structure and genesis; a structural classification of valleys; and a genetic classification of drainage systems. His classification of drainage recognized three modes of genesis, of which two were new. With the novel ideas involved in the terms 'superimposed drainage' and 'antecedent drainage' were associated the broader idea that the physical history of the region might be read in part from a study of its drainage system in relation to its rock structure." Another idea of the utmost importance to the science, that of "base level of erosion," we owe to these studies of Powell. Outside these greater monographs Powell published many shorter articles, and his complete bibliography includes 251 items.

As director of the Geographical and Geological Survey of the Rocky Mountain Region, Powell was authorized to engage other geologists, and he brought to his survey G. K. Gilbert and C. E. Dutton, whose monographs on the Henry Mountains and on the High

—*F. S. Dellenbaugh*

MAJOR POWELL WITH CHIEF OF THE PAI UTES IN THE COLORADO REGION IN THE EIGHTEEN SEVENTIES.

Plateaus of Utah later published by his survey are to-day among the great classics of the science. Gilbert became one of the very greatest of American geologists, and he has borne testimony to Powell's contribution of ideas to his colleagues.

> Gathering about him [writes Gilbert] the ablest men he could secure, he was always their intellectual leader, and few of his colleagues could withstand the influence of his master mind. Phenomenally fertile in ideas, he was absolutely free in their communication, with the result that many of his suggestions—a number which never can be known—were unconsciously appropriated by his associates and incorporated in their published results. I have elsewhere expressed the opinion that the scientific product which he directly and indirectly inspired may equal or even exceed that which stands in his own name.

Powell's studies of the Indian races began simultaneously with those on the geology of the West and were continued at every possible opportunity. We owe to him important pioneer studies, especially on the Indian languages, Indian handiwork, customs, mythology and philosophy, with their origin and tribal relationships. According to McGee the principle of genesis was the keynote of Powell's researches in ethnology and in general anthropology:

> He mastered the Indian languages, first as a means of gathering facts and later for their own inherent interest. . . .
>
> The published details of Powell's work fill volumes; yet in ethnology and general anthropology, no less than in geology, the larger share of the fruit of his vigorous thinking was turned over freely to colaborers, with a generosity unparalleled in the history of Science, to find its way into the general body of human knowledge under other names than his own.

But the period of Powell's life spent primarily as a research scientist was soon to be replaced by that of the administrator, and from now on until his retirement in 1894, his time and thought were to be devoted largely to the direction of great government bureaus. Almost simultaneously with the organization of his first survey department in the West, there had grown up three other organizations generally known respectively as the Hayden Survey, organized under the General Land Office, the King Survey, under control of the Army engineers, and the Wheeler Survey, also under the Army. The Powell Survey was organized under the Smithsonian Institution but was later transferred to the Interior Department. There was lack of coordination and an overlapping of work with consequent waste of public funds, and quite naturally each director was ambitious for his own organization and was in competition with the others to secure public support. As early as 1875 the need of combination under a single head had become apparent, and in 1879 Congress referred the matter to the National Academy of Sciences for rec-

ommendation. A distinguished committee was appointed from the academy, but it was largely through Powell's advice and initiative that the four surveys were in 1879 merged in a new organization administered under the Interior Department and known as the U. S. Geographical and Geological Survey. Because of the important rôle that he had played in securing this result Powell declined to have his name considered for head of the new organization, and Clarence King was by Presidential appointment made the first director. At the same time the Bureau of American Ethnology was created under the Smithsonian Institution to take over the ethnologic work of the several surveys, and Powell was at once made its director. After a little more than a year King resigned from the Geological Survey, as it was later called, and Powell was immediately named his successor. He thereafter served as director of both bureaus until 1894. It was under him that the Geological Survey grew and its policies were largely shaped.

There are administrators [says Charles D. Walcott] who achieve a fair amount of success through securing from the organization economical and efficient work along prescribed lines. These are, properly speaking, executives. There are administrators of another kind, who possess insight and creative ability, who have scientific imagination and the power of initiative. Their conceptions are broad and clear; they are not only masterful in execution, but fertile in suggestion and potent with the authorizing power. Among this class Major Powell was eminent.

From the start Powell elected to attack the larger problems of pure science and if the practical investigation of a mining district was to be made, those problems involved which were of a purely scientific nature were not overlooked. As one now surveys the noble series of monographs and of annual reports issued by the Survey and by the Bureau of Ethnology during Powell's term of office, he can not but be impressed with the large proportion which have become classics of the science. In no equal period since that time has any comparable set of publications been issued by the Survey. His was the most glorious period of the U. S. Geological Survey.

When in 1867 Powell made his first visit to the Great West, his keen mind grasped the future possibilities of this vast semi-arid region through irrigation, and from that time the subject was never laid down but became one of the major efforts of his busy life. In 1878 he brought out his monographic report on the "Lands of the Arid Regions of the United States," which was soon issued in a second edition. In this monograph he set forth with marvelous insight the essential conditions for irrigation, a formulation of the principles by which much of the later work was guided. As director of the Geological Survey, he soon enlarged its scope to include the investigations of water supply with special reference to irrigation. The flow of streams was measured, reservoir sites were surveyed and extensive researches were carried out upon the conservation of water supply. He thus trained the fine body of men who became known as "his boys"—the sons of the Reclamation Service as he was its father. No one better than Powell knew the irrigation possibilities, and he was determined that this great heritage should be vested in the people themselves so that they should never be robbed of their rights through the operations of water companies. Powell early saw that only the Federal Government could undertake such gigantic projects, which would require expenditures in the aggregate of billions of dollars. "The world owes the gift," says the historian of the Service, "to John Wesley Powell, the father of the Reclamation Service."

It was but natural that powerful private interests should be arrayed in opposition to Major Powell. At first he was

discredited because he boldly announced that only a small percentage of the West could ever be reclaimed, and he declared to be semi-arid the middle plains belt where the railroads were then luring settlers to their undoing. He pointed out clearly the evils which must be remedied through legislation.

The attacks upon Powell were aimed directly at the Geological Survey, and in 1892 his enemies in Congress delivered upon it a body blow which left it crippled to recover only slowly. During a luncheon recess of the Congress these men succeeded in bringing together a bare quorum and the Survey appropriation was reduced by almost one third. The day is well remembered by the writer, who received from the director a laconic telegram to stop field work at once, and similar telegrams went to field parties throughout the country. Not long thereafter under his successor the policy was inaugurated in the Survey of undertaking those studies only which could be seen to lead directly to a "practical" solution which could be measured in terms of dollars.

Two years later in failing health, Powell resigned his position as director of the Geological Survey, delegated the direction of the Ethnological Bureau, and the labors for a proper Reclamation Service had to be taken over by others, but mainly by the men he had developed. The bill which founded the great Reclamation Service was finally passed in 1902 with the powerful support of President Theodore Roosevelt. Powell, seriously ill and only three months before his death, was greatly cheered by the news of its passage.

Powell's interest in philosophy had been early stimulated by his study of the primitive philosophy of the Indian tribes, and with his retirement from administrative responsibilities, he turned to studies of psychology and philosophy, which took up his attention during the last eight years of his life. Four years before his death he published "Truth and Error, or the Science of Intellection," a book of over four hundred pages in which his philosophy is clearly set forth. In reading it one is constantly reminded of Huxley by its trenchant phrases as he hews to the line through some of the unrealities of metaphysics. I shall content myself by references to the opening and the closing pages of "Truth and Error," which in some measure indicate its trend.

Powell relates that once on the brink of the Grand Canyon he was in camp with Indians, and with their chief, Chuar, they amused themselves by throwing stones out over the canyon in a vain attempt to reach the other wall. Chuar expressed the belief that he could throw a stone much farther over the plateau than he could over the canyon, and he explained that the canyon pulled the stone down. He thus reified void and imputed to it the force of a pull.

> Now [says Powell], in the language of Chuar's people, a wise man is said to be a traveller . . . as they suppose that a man must learn by journeying much. So . . . I told Chuar that he was a great traveller, and that I knew of two other great travellers . . . one by the name of Hegel, and another by the name of Spencer, and that I should ever remember these three wise men, who spoke like words of wisdom, for it passed through my mind that all three of these philosophers had reified void and founded a philosophy thereon.

The sentences which conclude the volume are: "The war of philosophy is between Idealists and Materialists. The philosophy here presented is neither Idealism nor Materialism. I would fain call it the Philosophy of Science."

A second volume entitled "Good and Evil" appeared in serial form as separate essays, but was never brought out in book form, and a third volume, planned to treat of the emotions, was never completed. As a philosopher Powell was but little known, but his

vigor of thought and clarity of expression merit a wider consideration.

In later life honors poured in upon Powell. He was elected to the National Academy of Sciences, the American Philosophical Society and the American Academy of Arts and Sciences. Harvard University and the Columbian University, as well as many other institutions, conferred upon him their honorary degrees of doctor of laws, and the University of Heidelberg in Germany made him an honorary doctor of philosophy. He was elected to the presidency of the Geological Society of America and the American Association for the Advancement of Science. He was president of the Anthropological Society of Washington from its foundation in 1879 until 1888. In 1891 the French Academy of Sciences awarded him the much coveted Cuvier Prize.

In personal appearance Powell was a notably rugged type, a hairy man with large bulbous nose, a patriarchal beard, and with rather small eyes under bushy eyebrows. In later life his face was deeply seamed, which might tell something of what he had suffered from torturing pain. His figure was that of a sturdy oak, gnarled and seamed and with severed limb, which had withstood the blasts of many winters. The face was not a handsome one, but it was one which could not be overlooked in any assembly.

As a man Powell was in high degree self-contained, and his intimate friends were in consequence a small company only, though he drew a host of others to admire and love him. Referring to his associates on the occasion of his retirement from the Geological Survey, his valedictory statement is full of pathos:

> In this severance of our relations [he wrote], made necessary by painful disability, I cannot refrain from an expression of profound gratitude for the loyal and loving aid which they have given me, ever working together with zeal and wisdom to add to the sum of human knowledge. The roster of these honored men is found in ten-score volumes of contributions to knowledge and fifty-score maps familiar to the scholars of the world, and their names need no repetition here. . . .
>
> With feelings of deep endearment I say good-bye.

He died at his country home at Haven, Maine, on September 23, 1902, in his sixty-ninth year. One of his closest friends, Dr. S. P. Langley, then the distinguished head of the Smithsonian Institution, has written feelingly of him:

> If there be anything outside the soldier, the explorer, or the man of science, it lay in a singularly simple and strong humanity; a something which took hold of you and made you his friend. While he was here he filled an almost unique place in one's life, and now that he is gone there remains a gap which no other can fill. . . . He was a Stoic who suffered long years of pain in silence and who at the end met the approach of death as though it were a familiar incident of life. . . . We shall not often look upon his like.

IS A SCIENCE OF EDUCATION POSSIBLE?

By Professor FREDERICK S. BREED
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During the present exciting field day for critics of our commercial and industrial system, our banking and education, our morals and religion, our liberalism and democracy—our social institutions in general, each must determine for himself the value of an answer to a destructive assault. The formula for the fame of the headlines is simple enough and widely diffused: crack down a public idol with iconoclastic zeal or kidnap him. On occasion one discerns a glint of wisdom in the weathered old Canadian settler who, when he received a bill for taxes in figures of disturbing magnitude, was never at a loss to know how to dispose of it. Documents of this description were summarily devoted to the primordial derisive use of such impertinences.

An article which recently appeared in *Harper's Magazine* under the title, "Educators Groping for the Stars," should be spared the cruel fate of insult added to the injury of neglect, and for two reasons. First, though negatively vigorous, it is constructively negligible. Second, it is not even dependable in its vigorous negation. It brings to mind the penchant for misinformation and distortion exhibited by a young lady described by Stratton Brooks when he was superintendent of the Boston public schools. "She was a splendid teacher," he said, "of things that aren't so." In their enthusiasm for scientific research, the author, Mr. Nathaniel Peffer, charmingly likens educators of the present to the legendary general who at the first sound of alarm flung himself into the saddle and rode off in all directions at once. Peffer, of Guggenheim affiliation, bears a closer resemblance to our own General Hooker, who shortly after his appointment to the command of the Army of the Potomac, is reported to have sent a message to President Lincoln embellished at the top—"Headquarters in the Saddle." Lincoln read the message, then drily remarked: "There is only one trouble with Hooker. His headquarters are where his hindquarters ought to be."

A careful analysis of the article soon throws the causes of irritation into bold relief. Educators are suffering from a species of "frenetic inflation," "grandiloquent fancies," "wild divagations" and the excessive "altitude of their ambition."

"I beg your stuff?" says Baron Munchausen.

Well, a less rhapsodical diagnosis of the malady shows it to be threefold. It consists of the misguided adoption of the following aims: (1) Reconstruction of the social order, (2) integration of individual personality, (3) scientific investigation of educational problems.

A coterie of educators has been discovered whose central objective is the reconstruction of the social order. These educators have been greatly impressed by the bolshevist movement for social reform in Russia. They favor national planning and a collectivistic state. They would even enlist the energies of the schools in subversive activity for the accomplishment of their revolutionary ends.

As a judge in Pittsburgh recently remarked, "These fellows are not educators; they should hire a hall and go into politics." Too true. They represent neither the educational sentiment of the nation nor the views of the vast

majority of intelligent leaders. They represent the radical fringe. Moreover, they have undertaken a task of leadership that calls for competent specialists in the social sciences, when there is not a sociologist or economist or political scientist of recognized scholarly standing among them. It is obvious, then, that I have no quarrel with one who disputes the ambitious claim of these revolutionary agitators in pedagogical clothing. I even admit that a genuine service has been performed by turning a searchlight on the weaknesses of their position. I simply resent the implication that this type of radicalism has seriously infected, much less permeated, the real educational leadership of the nation.

Nor do I object to the outburst against those who worship at the mystic shrine of "integration." When vaguer educational aims are made, such people will make them. But after a valiant effort to relieve education of irrelevancy and mistiness, of social reconstruction and individual integration as basic purposes, Mr. Peffer, with curious inconsistency, ends his discussion by lifting John Dewey to a lofty pedestal and bowing down in worshipful regard to him as one "who has been our greatest pioneer in educational thought." This in the face of the fact that both of the doctrines so bitterly attacked have been absorbed in the program of the self-styled progressive school in education, of which Dewey is high priest and acknowledged leader. The doctrines, social reconstruction and individual integration, are not horrible examples of "a superficial rendering of John Dewey's educational philosophy." They bear the stamp of his approval in authentic documents. He is the open champion of both.

The third distressing feature of modern educational policy, we are informed, is the adoption of the scientific method. This policy is judged the ill-starred child of much beclouded brains. And what a comedy of errors it seems to entail. "All that education has taken over from science," our critic contends, "is the word research. By its very nature that is all it can take, for it deals with too many factors which are imponderable, which by their very essence are not measurable by fixed and unchanging standards."

The picture which is painted of the attempts of educators to apply scientific methods in the investigation of their problems is a product of the misinformation and distortion earlier referred to. The outmoded questionnaire, precarious tests of character traits and rating scales for measuring qualities of personality are held up as representative of techniques regarded by educators as scientific, when the truth is that the questionnaire method, except as a legitimate index of mere opinion, is in thorough disrepute among educational investigators; the problem of measuring such character traits as loyalty and leadership is known by them to be unsolved; and the rating scales employed on occasion by superintendents of schools in estimating the degree of certain desirable personal traits possessed by teachers have been shown by educational experimentalists themselves to be highly unreliable because highly subjective.

Now let us bend a little nearer to our task. Is there any possibility of a science of education? If there is, it will not be discovered by negative dogmatists. Nor will the possibility of such a science be demonstrated by abortive examples, like those cited above. But even on these examples one can look with a measure of tolerance if one stops to reflect that not every pedagogue who mails a questionnaire is entitled to represent the scientific personnel of his profession, that in many fields the desired objectivity of method is achieved only after repeated failure, and that the possibility of a science of education

must be judged by the best and not by the worst of its investigations.

It is a commonplace to remark that science and measurement develop hand in hand. As methods of measuring are devised, science advances. This has been notably true in physics, which has been taken as the pattern for all exact science. The laws of physics are based on facts determined by measurement—facts regarding the mass, volume, temperature, velocity, and the like, of objects. Such terms as these denote either qualities or relations between qualities. Temperature is a quality of an object. Velocity is the ratio between a spatial and a temporal quality.

$$V \text{ (velocity)} = \frac{d \text{ (distance)}}{t \text{ (time)}}.$$

That is, if I divide the distance you run by the number of minutes you run, I have your rate, or velocity, of movement. If v remains constant while both d and t change, we have an example of the type of uniformity that science discovers in the midst of change.

Now let us revert to our qualities for a moment. We spoke of the qualities of an object, but on reflection it becomes evident that an object of perception is a combination of qualities. By measuring the qualities one measures the object. Moreover, one measures the qualities in *amount*. Length is a quality of an object and is measured in amount by an instrument known as a yardstick. Temperature is a quality and is measured in amount by an instrument known as a thermometer. Every quality seems to come in some amount. It possesses either extensive or intensive magnitude, each of which is measurable with more or less exactitude. It should be observed, further, that the measurement is always in terms of arbitrary units on a scale. As Eddington has said, measurement always resembles the action of a pointer on a dial. Indeed, a quality in last analysis becomes to science an event coordinated with another event. Measurement expresses a relation between events. Something happens and the pointer registers something. That is measurement. And, finally, the measurement never has the perfection of accuracy so commonly supposed. Every measurement is a statistical approximation.

In the interest of clearness it may be well to dwell a moment longer on the last preceding point, for many persons no doubt still believe that scientists, especially physical scientists, can measure with greater precision than was just indicated. The difficulties in the way of perfect measurement can be illustrated, however, by a very simple example. Suppose I bring forth a yardstick and ask each of a group of scientists to measure the length of my desk to the nearest inch. When the results are announced I would expect no variation among them, unless perchance one of my guests became so bored by the triviality of the task that he absent-mindedly forgot the assignment. We shall endeavor to awake even his interest by next asking for a measurement to one thousandth of an inch. Now the difficulties begin to pile up so fast that we shall not have time to enumerate them. Immediately I hear a demand for a more accurate instrument of measurement, a demand for specification of the point on the side of the desk from which the measurement is to be made, and the like. I insist, however, on the original problem—measuring the length of the desk with the yardstick, and this time I shall be surprised if any two measurements agree. Even if the task be made more specific and a finer instrument be supplied, all I need to do to prove my point is to reduce the size of the unit on which I demand agreement. A light-year is the yardstick of celestial measurement, yet no astronomer knows precisely the velocity of light. Atomic weights are

basic units in chemical analysis, yet no chemist knows the precise value of a single one.

When, now, one turns from the field of physical measurement to that of mental measurement, the fundamental principles are found to be the same. Early skepticism in regard to the possibility of mental measurement probably grew out of the belief that it is ridiculous to think of laying a yardstick on an individual's stream of consciousness or on his psychic states. It *is* ridiculous. Modern educational and psychological investigators have no such preposterous purpose as measuring states in the stream of consciousness. Many of them have even discarded the notion of a subcutaneous mind—whether in the form of a soul in the pineal gland or of sensory ghosts in the brain cells.

The chief function of all education is direction of the learning process. Learning therefore becomes the first topic of interest to educators. Can learning be measured? Certainly. It is something that is directly observable and can be measured as simply as the reactions of people can be measured, for it is a *change* in reaction, a modification of the behavior of an individual. The real test of learning is the acquisition of a selective reaction to an object or stimulus. One merely presents a stimulus to a pupil and notes whether or not the desired specific reaction is made. This is the methodology of modern educational tests and can be illustrated by the following items clipped from a standard test on knowledge of literature:

75 "Lead, Kindly Light" was written by
Carlyle Cardinal Newman Phillips Brooks
76 "Captains Courageous" is about
Ben Gunn Diska Troop John Silver
77 "Flow Gently, Sweet Afton" was written by
Burns Keats Tennyson
78 "The Ancient Mariner" was written by
Browning Coleridge Longfellow
79 "Annabel Lee" was written by
Poe Longfellow Wordsworth

The test item in each case is the stimulus, to which the pupil reacts selectively by underlining the name of the author or character that makes the sentence true. The stimulus may be a real object, but it is usually a verbal substitute therefor. By this technique there would be no special difficulty in measuring the degree of acquaintance of the reader with authors and characters or in finding out how much he has learned regarding them during a given period. In the latter case two tests of equal difficulty covering the field and separated by the desired interval are used. These are called duplicate tests.

The technique of educational and psychological measurement is objective enough to satisfy the most rigorous demands of the most ardent behaviorist. The modern tester may not deny that psychic states exist, but so far as he is concerned they might well be non-existent, for he has no commerce with them. A standard educational or psychological test is nothing more than a series of stimuli. The stimuli are objective in the strictest sense—their existence is verifiable by another observer. The pupil's reactions to the stimuli are objectively recorded. Usually they are recorded in pencil by the pupil himself on a test sheet. His score on the test is simply a summarization of the reactions.

Tests of this character measure directly, then, the objectively observable reactions of pupils. More specifically they measure qualities of reactions. The qualities most commonly measured are accuracy and rate. Standardized tests are now available for the measurement of accuracy and rate of reaction in many areas of instruction, including reading and handwriting, spelling and computation, vocabulary development and problem solving. Accuracy and rate, like any other qualities, are measured in amount. If a pupil responds correctly to 75 out of 80 items in the word-meaning section of the New Stanford

Achievement Test, his percentage of accuracy is clearly 94. His rate is measured by a stop-watch.

In this manner many types of mental content and activity can be measured. When and if all types are measured, mind will be measured, for, so far as we know, a mind and its activity are nothing more than a manifold of terms in certain relationships. We can discover what one knows about banking or foreign exchange, Latin or the tariff, and we can discover how accurately one can put two and two together in these fields. All that is necessary is the presentation of a sufficiently large number of representative problems and items of information. This is a matter of random sampling, as is all such testing. From the significant material in the field one selects items in sufficient number to yield an accuracy score approximately equal to that which would have been obtained if all the items in the field had been presented.

For the success of this plan it is obvious that two things are needful: First, knowledge of the most important content in the field in which the testing is to be done and, second, the proper sampling of the content. Few people outside the teaching profession are aware of the vast amount of detailed objective work that has been done to discover the important materials in various subjects of study. Take spelling, for example. Consider first that the demand for spelling arises in life when one is attempting to express one's thought in written form. The central aim in the teaching of spelling, therefore, is to enable the individual to write correctly the words that are needed in his written discourse. Can these words be discovered? They have been discovered. They have been discovered by tabulating all the different words found in the written work of thousands of children and adults. Millions of running words have been thus tabulated from the themes and letters of children, and from the business and friendship letters of adults, with the frequency of occurrence of each word. The results have been nothing short of a godsend to the millions of boys and girls in the public schools, for whereas pupils were formerly required to learn the spelling of as many as 12,000 to 15,000 different words, to-day, where schools are scientifically organized, the number of words in the elementary grades has been reduced to about 4,000. The reduction was made possible because it was found that if one learns to spell no more than the 500 words of highest frequency in the 4,000, he will be able to spell 82 per cent. of all the running words used by ordinary adults, and if he learns to spell the whole 4,000, he will be able to spell correctly nearly 99 per cent. Within the range of a reasonably small probable error, the words that children should be taught to spell are known. And with this first problem solved, the second requirement becomes nothing more than a mechanical procedure. The only serious question relates to the size of the random sample, and statistical studies show that for a sufficiently reliable measurement of an individual pupil on a year's work in spelling, a test containing at least 50 words is necessary.

Now a word in regard to accuracy of measurement. This is an extremely important question, for it has even led some of our educators to abandon hope and exhibit all the earmarks of an inferiority complex. Such self-abasement might be more unbecoming in a drum major, but it would not be more unnecessary. In education and psychology we not only measure quantitatively the quality of objectively observable events, but like the physical scientist and by the same method we determine the reliability of the measurements. This is done by the computation of the probable error of measurement, a relatively simple

statistical process well known to workers in science.

For the best tests in school subjects the probable error of a pupil's score from a single competent measurement has been reduced to 2 points on a 100-point scale. This error is still very large in comparison with the probable error of physical measurements, but its size is no reflection on educators. Greater accuracy of measurement is in general possible in physical than in biological or psychological science, primarily because of difference in material measured. There are two outstanding conditions that interfere with accuracy of measurement—variability of the matter and variability of the manner, and in mental measurement the first is the worst offender. A block of material on the frame of a ten-story building has a remarkable consistency of behavior compared with the block on the frame of a ten-year- old boy. The size of the probable error is due much less to the wobbling of the tester than to the wobbling of the testee. In any case a measurement must always be as wobbly as that which is measured. Now if a boy obtains a score of 67, with a probable error of 2, just how variable is such a score? A score of 67 ± 2 means that if he were measured an indefinitely large number of times by competent testers, half of the scores would be between $67-2$ and $67+2$, or between 65 and 69. In other words, there is a fifty-fifty chance that the boy's true score will not vary from 67 more than 2 points either way. This degree of accuracy in educational measurement has become possible only since 1910, when the conception of the standardized educational test and the method of constructing an educational scale were made known.

Educational measurement is still in its early infancy. A quarter of a century is but a day in the life of such a development. Yet in spite of its youth it already has a clear grasp of the principles underlying its program and faces its future as well as its critics without apology for its existence.

Educators can be classified into three fairly well-defined groups: (1) the traditional, (2) the scientific and (3) the philosophical. This is a conservative-liberal classification and is made in terms of the most important dimension of social leadership and social institutions. The traditional group represents extreme conservatism and is primarily interested in the preservation of the *status quo*. The scientific group is conservatively progressive, and the philosophical group, known more commonly as the "progressive" school, harbors the radicals of the profession. Our critic castigates the radical and scientific groups, then fervently prays for an educational holiday. "I suggest," he says, "that educators take themselves at whatever point they now find themselves, resolving only to do well that which they are now doing." Thus he turns to rugged traditionalism as a means, one surmises, of placing education on a Guggenheim foundation. Why not try to put it on a scientific foundation? This would solve the problem for one who desires to escape the stagnation of traditionalism on the one hand and the uncertainties of radicalism on the other. For such a one the educational slogan would be, As progressive as science.

A SCIENTIFIC APPROACH TO EMOTIONAL PROBLEMS

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It is alleged that one of those dubbed "brain trusters" has asked what part of the body can be trusted better than the brain. The difficulty is that some of those in the saddles at Washington tend to trust the heart rather than the brain. To a professional psychologist, who is an amateur economist, it seems that the President is a better practical psychologist than he, a more amateur economist. A scientific approach to the emotional side of economic problems is not easy.

Laplace, the great French mathematician, proposed an equation to the effect that the *fortune morale* is equal to the logarithm of the *fortune physique*. A corresponding psychological formula was later developed by Weber and Fechner, stating that the intensity of sensation increases as the logarithm of the stimulus.

If, for example, a room is lit by one candle, an additional candle greatly increases its illumination; if it is lit by 100 candles, an additional candle makes a difference that can scarcely be seen; if it is lit by a thousand candles, an additional candle makes no perceptible difference. If the difference in weight between 10 and 11 ounces is just perceptible, there is no noticeable difference between 10 pounds and 10 pounds and one ounce; the difference must be a pound—16 ounces, one tenth of the magnitude—in order that it may be perceived. As the result of many thousands of experiments the present writer has concluded that the just perceptible difference increases more nearly as the square root of the stimulus than as its logarithm, but that is irrelevant to the present argument.[1]

The analogous social and economic situation, stated long ago by Laplace's equation, is that the value of money to the individual is proportional to the logarithm of its amount. One dollar's increase or decrease in income for a man earning $1,000 a year is about as significant as $10 for a man with an income of $10,000, or $100 for an income of $100,000. So long as the satisfaction purchased by money increases more slowly than the amount, whether the relation is logarithmic as Laplace proposed, or more nearly as the square root as the present writer holds, the important conclusion follows that expenditure of money would tend to purchase the greatest satisfaction if the incomes of all were equal. If this scientific deduction has been made hitherto it has not received attention.

Weber's psychological law is subject to many qualifications due to special conditions; the same is true of Laplace's economic law. The scientific man should be allowed as much money as he can use to advantage for books and apparatus; if

[1] Most people imagine that as a penny is tossed there will be an increasing likelihood of an equal number of heads and tails. A distinguished biologist once bet an article for The Scientific Monthly against $100 that there would be a smaller disparity between heads and tails with 10,000 throws than with the first 1,000. He threw coins 10,000 times—and won! But he would not now repeat this bet. As a matter of fact the disparity tends to increase as the square root of the number of throws; this is what might be expected in psychology or economics when we are concerned with a large number of small causes equally likely to be positive or negative.

a Beethoven even imagines that he composes better with champagne than with beer, he should have the champagne; those engaged in disagreeable or dangerous trades should be paid more than the average. The ideal should be: From each according to his ability; to each according to his needs.

It is possible to be a radical in ends, an opportunist in methods; a socialist in economics, an anarchist as to thought and behavior. It does not follow from Laplace's equation or from the application of common sense to economics that wealth can or should be distributed equally to-morrow, or necessarily at any time. Competition for money may be necessary to assure the best work of which a man is capable. The accumulation of wealth in private hands should continue until public agencies learn to conduct business efficiently and to give adequate support to education, scientific research, art and the like.

While it may be that wealth can not now and probably never should be distributed equally, a useful lesson may be learned from considering what would happen if it were. If the income of the country were equally divided among all, each would now have to spend, after deducting direct and indirect taxes and allowing a small margin for saving, less than $400 a year. In full prosperity it may have been $600. With better organization of industry and further applications of science it may become $1,000, perhaps $2,000, ultimately even more. At present, however, there is at most $400 for each of us, and while the dollar is still worth 100 cents, it will tend to become worth 60 pre-Rooseveltian cents.

It may be that in a period of depression work should be shared with the unemployed by prescribing a short day's work, though this is doubtful. As a permanent policy it would be disastrous. Before the industrial revolution most men, women and children worked twelve or more hours a day and got black bread, hovels and lice; people died at the average age of thirty years or earlier. Now, thanks to the applications of science and the better organization of society, child labor has become intolerable; eight hours of work for six days a week will provide the necessities and many of the comforts of life. The average length of life has been more than doubled.

Thirty hours of work a week will today supply the necessities of life, but not the comforts. The hours should not be longer than is compatible with the health, happiness and efficiency of the worker, but it seems that he should be permitted to work thirty hours a week and live meagerly, or forty-five hours and have 50 per cent. more money, which could be used for bathtubs, telephones, radios, cars and children.

It is said that when a New York City magnate was asked whether he got most gratification from his steam yacht or private railway car, he replied that he did not see how any one could get on without either. If this represents the good will of the magnate to the wage earner, it is commendable; but, apart from yachts, it is obvious that on an annual income of $400 per person every one can not visit the National Parks in his own car.

The present writer is a code authority, also a member of one of the trade unions of the American Federation of Labor. In the industries with which he is concerned—publishing and printing—the 40-hour week has been maintained in the interest of the industry and of the workers. In other industries the unions want to decrease hours and increase wages. About half the people of the country should be productive workers; the other half are dependents. This means that an average of not more than $800 a year is available for each worker.

So long as many tens of thousands of

men and women have annual incomes, earned or unearned, of from ten thousand to more than a million dollars, it is obvious that each worker must on the average be content with an income smaller than eight hundred dollars a year. If he wants an income larger than $16 a week, he can get it only by taking it from those with larger incomes, which is difficult and would not go so very far if distributed among sixty million people; or, which is not so difficult, take it from those who have even less than he.

Although it is more than his share, it is reasonable at present for a worker to try to obtain $16 a week if he works 40 hours, $12 if he works 30 hours. If there is complete recovery and a better organization of industry he can look forward to earning $32 or $24. These wages can be materially increased only by increasing production through new advances in technology or more efficient management and work. The worker is within his rights in trying to get all he can from capital and management, but the way by which he can increase wages for all under existing conditions is not by strikes or walkouts, but by cooperating with capital and management in increasing production.

There is overproduction in some directions—for example, in wheat and cotton, in wood-pulp magazines and sex movies—but there can not be overproduction as a whole. Owing to bad adjustment to a changing social and economic order, there is an appalling amount of underconsumption. There are about as many automobiles in the country as there are children; it costs about as much to buy a car or to keep it for a year, as it does to get a child or keep it for a year—according to the wealth of the individual, say $100 to $10,000 for each of the four objects. There has been overproduction of cars and underproduction of children; the available income of the country does not suffice for both. Children are worth more than cars, if only because they grow up to be productive workers worth $20,000 each, while cars wear out. Children should be paid for by the state, perhaps from a 100 per cent. tax on cars.

Problems should be solved by scientific method; ends can only be attained by emotional appeal. Verses are consequently here quoted. These two stanzas are by Edward Tregear, a New Zealand poet:

Peril is here! is here! Here in the Childless Land
Life sits high in the Chair of Fools, twisting her ropes of sand;
Here the lisping of babies and cooing of mothers cease;
Here the Man and the Woman fail, and only the flocks increase.

Axes may bite in the forest, Science harness the streams,
Railway and dock be builded—all in a Land of Dreams!
Sunk in spiritual torpor ye flout these words of the wise
"Only to music of children's songs shall the walls of a Nation rise."

A similar emotional appeal is made in the following verses in the form of a sonnet:

Knowledge may multiply and wealth increase;
Science may drive his chariot through the skies,
And scatter trophies of his enterprise,
Into the laps of all with no surcease.
Men may be bred to luxury and ease,
Unmindful of the labors of their past;
War, pestilence and famine may at last
To peace, long years and plenty sign release.

But what of that, when children fail the land;
When unnursed women walk the market place,
More shameless than their sisters of the dark,
For all their husbands' names: These with the mark
Of Onan's tribe. Where is the infant hand,
Whose touch alone can heal a dying race?

The abolition of child labor, a minimum wage and collective bargaining are admirable ends; but they should be at-

tained by pressure of public opinion on the Congress, not by fascist decrees and NRA boycotts. Executive decrees, even more than acts of the Congress, may run wild.

When the depression has been caused largely by overborrowing, it is not likely that it can be cured by more borrowing by federal, state and municipal governments. When prices fall through lack of purchasing power, purchases are not likely to be increased by higher prices. Inflation wipes out debts, savings-bank deposits, life insurance policies, etc., and reduces the purchasing power of wages and salaries. Any stimulation that it gives is about as effective as a drink of whiskey.

To "regulate the value" of money is among the powers granted to the Congress by the Constitution, but to do so by artificial measures is probably unwise. It is dishonorable for a government to break engagements that it can keep. Germany and France were forced to repudiate debts by hard necessity. Great Britain did so to a lesser extent because it had no gold and hoped to get it by reducing real wages and increasing exports. We decreased the value of the dollar when we had idle and useless gold worth billions of dollars.

This action of Great Britain and the United States was lawful; as a matter of policy it is arguable on both sides. It is, however, distressing to those bred in the Anglo-Saxon tradition of commercial good faith. It is not a matter of policy but of morals for the government to keep its word; when it refuses to redeem gold certificates with the amount of gold promised and makes the ownership of these certificates a crime, it can only be said that the government in creating a crime has committed a crime.

Economics has been called the dismal science; now amateur economics seems to be an exciting adventure. Try fake remedies and stop them when they don't work—if you can. We are in the midst of an agricultural revolution corresponding to the industrial revolution of a hundred and fifty years ago. Then the weavers in the cottages were gathered into factories; England has since supplied the world with cotton goods. Thanks to the applications of science wheat can now be raised profitably under proper conditions for forty cents a bushel. Pity the poor farmer, certainly; but the lot of his grandchildren will not be bettered by killing pigs and plowing cotton under. When the price of wheat is put up to over a dollar a bushel, a sales tax of 100 per cent. is imposed on bread, which exacts tribute from those least able to pay it.

What then would scientific method do if applied to the present economic and social situation? Science is common sense carried to the limit of human ability. The proper course for a nation to follow in a time of depression is presumably what a man should do when hard up as a result of extravagance, borrowing and neglect of his business. If he is a decent man he will work hard and long, live frugally, avoid waste, improve his business methods, pay his debts, accept charity only as a last resort. Men, organized in government, should do the same.

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RACE CROSSING AND HUMAN HEREDITY

By Dr. MELVILLE J. HERSKOVITS

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AMONG the few statements that the scientist who studies human beings may make without fear of serious contradiction is that human groups do not meet but that they mingle their blood-streams. Whether in the Far East, where Europeans and Orientals have merged to form the great Eurasian populations found there to-day, or in north Africa, where folk of Negroid and Caucasoid derivation live, or in Yucatan, where the descendants of crosses between Spaniards and Maya Indians are found, evidences of mixture are to be discerned.

Nor is this something recent, for crossing has been going on for countless ages. Indeed, the matter becomes the more impressive when it is realized that no matter how rigidly restrictions against crossing are set up, they do not seem to be of any avail. The stigma that was attached to one called "squaw man" in the days of the American frontier—that is, to the white who mated with an Indian—was expressed in social ostracism; in India, eternal punishment is believed to await a person of caste not only for mating with an outcaste, but for even so much as touching one.

Yet attitudes and beliefs of this kind have not proved strong enough to prevent mating across any line that society may draw. Though death and torture have been decreed as penalties for forbidden contact, especially where two groups marked with strikingly different physical characteristics and representing different strata in the population have been involved, there is no record to justify the conclusion that even the most extreme measures have had any great effect in prohibiting racial mixture.

This means, then, that all human groups living to-day are of more or less mixed ancestry, that no "pure" race may be said to exist. Yet we must recognize the fact that some crosses have occurred between peoples of more dissimilar physical characteristics than has been the case with other mixtures, and that it is in the former instances that the term "race-crossing" is properly applied.

Since we have the subject of race-crossing under consideration, we must attempt a working definition of the word "race" before we proceed further. There are many implications of the term that we can not touch upon here, and the word has been sadly misused; but the anthropologist usually employs it to mean the three major divisions of mankind, called Negroid, Mongoloid and Caucasoid. Furthermore, in scientific usage, it signifies with few exceptions only the physical traits that are distinctive of these respective groups.

Scientifically speaking, therefore, race-crossing is crossing such as we have experienced here in America, that has produced the considerable section of our population we term Negro, but which is in reality a mixture between African Negroids, European Caucasoids and, to a much larger extent than is ordinarily thought to be the case, Mongoloid American Indians. The term may also be applied with propriety to such other groups as the mixed Maya Indian-Spanish people of Yucatan who have already been

mentioned, to the Bastaard folk of South Africa whose ancestry is derived from Boers and Hottentots, and to the Dutch-Indonesian population of the Island of Kisar in the East Indies, where European soldiers long ago mated with native women. In this category must also be placed the descendants of the British sailors who were involved in that romantic episode of the early history of the South Seas, the mutineers of the *Bounty*, who took Polynesian women as wives.

In such populations, descended from ancestors having the most dissimilar physical traits, the student of human heredity finds the most fertile field for his research. For it is in the nature of the study of any aspect of human biology, but especially true of genetic studies, that the practical difficulties in the way of obtaining adequate material present the most serious stumbling-block the student must face. Obviously, it is not possible to segregate and breed human beings in the manner in which fruit-flies or guinea-pigs or white rats are segregated and bred; we who would study human heredity must take the wide world as our laboratory, and our "experiments" can not be set up by ourselves and repeated at will, but must be those set up for us by history. Historical contacts such as have resulted from the invasion of North Africa by the barbarians in Roman times or the expansion of European imperialism in the seventeenth century or the African slave-trade of the eighteenth and early nineteenth centuries have made race-crossing possible on a scale that allows profitable research into the questions of human heredity.

Another difficulty faces us, however, even when the historic development of a people has made of them an example of racial crossing of the type available for study. Geneticists, in their laboratories, work with rapid-breeding forms which, in addition to reproducing often, give birth to large numbers of offspring. Man, however, is not only a slow-breeding animal—as long-lived, indeed, as the student of man—but the number of offspring produced by any given mating is so small as to be almost useless for purposes of mass studies. In surmounting this second obstacle, the technique to which we have recourse is a statistical technique. Instead of studying a quick-breeding animal which reproduces great numbers of offspring, we obtain measurements and observations on large numbers of families—parents and children—and thus match in the numerical breadth of our data the depth in generations of the data available to the animal geneticist.

With a racially mixed population available for study and facilities for studying them at hand, the anthropologist makes his measurements. These may include any number of the traits that distinguish one race from the other, one individual from the next. One may record the time-hallowed head-measurements or may study unusual dimensions such as the length of the middle finger. In the main, in studies of this type, the traits that are measured depend upon the characteristics in which the two parental stocks are most different. Thus, in an investigation of the results of crossing short-headed French with long-headed Indians, the shape of the head would be an important trait; if the cross were between long-headed Britishers and long-headed West Africans, the shape of the head would be of relatively small significance. In this latter case, it would be much more important to study what had happened to the thickness of the lips or to the width of the nostrils or to the different bodily proportions which characterize the two parental types.

Practically every study of a racially mixed population that has been made in the past decade has been concerned with the problem of the extent to which

operation of the rules of Mendelian heredity can be discerned in the offspring of human matings. While these rules of heredity have been established for practically all animals and plants whose genetic composition has been studied, the attempts to find the expected results in human offspring have brought us to no definite conclusion.

Does this mean, then, that humanity represents a special biological type, exempted from the operation of the principles of heredity that apply to other forms? The answer to this question must be a decided negative. It is because the practical difficulties in the way of obtaining properly controlled material and of studying human families through succeeding generations are so great that our information is fragmentary, and does not allow us to give satisfactory answers.

There is a further reason why it is difficult to answer the questions that are raised concerning Mendelian inheritance in man. In all branches of science, problems that at first seem simple become unbelievably complicated with prolonged investigation. This has been the experience of those who have studied the Mendelian inheritance of physical traits in lower, rapidly breeding forms; the carriers of the unit-traits have been found to be more and more complex in their structure, so that to-day instead of the chromosome, we regard the gene as the carrier of inherited characteristics, and it is the nature of the inner structure of the gene that is being made the object of research by many geneticists.

Therefore, when one asks the question, "Does Mendelian heredity apply to man?" the answer must be couched in the form of another query: "Is simple Mendelian heredity meant, or is it the complex type of multiple Mendelianism of which the geneticist speaks at the present time?"

To this rephrasing of the original question, the answer is clear: Simple Mendelian heredity is no more apparent in man than in the lower forms, where it appears rarely, if ever; multiple Mendelian heredity has not been found in man for the reason that we have as yet no adequate technique of studying such complicated problems. It must again be stressed that we do not deny the operation of any form of heredity in man that can be established for the animals; it is when it comes to scientific proof that faith in the truth of such a statement must remain in the realm of faith.

What, then, do we know of the processes of human heredity as these are indicated in the study of mixed population groups? For one thing, the study of these groups shows us how it can come about that a people originally derived from different races may, over a period of time, give the appearance of what is called a "pure line." Obviously, it takes many generations to produce such unity of type in a mixed population. The general principle, however, that would seem to come out of the studies on peoples of racially mixed origin is that no matter how diverse the ancestral stocks from which a given people are descended, if there has been enough inbreeding after the initial period of crossing the families come to be like one another, and after a sufficient number of generations, such a people comprises many individuals who resemble each other to a striking degree.

This is true of the Pitcairn Islanders, who, descended from the mutineers of the *Bounty* and native Polynesian women, have lived in such isolation that the present generation represents a type neither European nor Polynesian, but a homogeneous combination of the characteristics of both races. The same, to varying degree, is true of the other mixed groups that have been studied, and when we express this in statistical terms, as we must, we say that a people who are homogeneous possess low variability. Relatively low variability char-

acterizes the Boer-Hottentot crosses of South Africa and the Mestisos of Kisar, while one of the most striking examples of this is found among the American Negroes. Here, because of social rather than geographical isolation, the variability of American Negroes in numerous physical traits, if compared with that of the general white population, is found to be lower than is the case with the whites.

In terms of the principles of heredity, this would seem to make less valid the concept of the "throw-back" that has occupied such a large place in our thinking on the subject. There seems to be some principle at work—call it multiple Mendelianism if you wish—that causes the members of these mixed populations to merge the characteristics of both parental types, so that somewhere between the ancestral extremes a combination of those types is achieved. While it is true that the limits between which the physical traits of a given person may conceivably vary are set by his total ancestry, the mathematical chances of his having any but the traits of relatively recent forebears seems to be so small as to be negligible. This is why the "throw-back" is heard of more in literature than in life, and why it is possible to combine people of two extremely different races into a homogeneous folk.

This conclusion, which is so strikingly different from generally accepted belief, is not without practical significance. Though instances might be given from almost any crossed population to make the point, an example may be chosen which is of peculiar interest to us in this country. I refer here to the deep-seated tradition that holds over the head of a person having any degree of Negro ancestry, be it even so small as one thirty-second or one sixty-fourth, the threat of having a "black baby" as offspring. We all know of the plays and the novels that have been written on this theme, we have all read newspaper accounts, or heard of instances where this is said to have occurred. Yet the scientist, when he seeks proof in the face of so many reported births of "black babies," finds verification strangely difficult.

What light does the study of Negro-white crossing throw on the matter? In the course of some research carried on a few years ago, we took readings of the skin-color of large numbers of American Negroes and their children. When the figures were in, it became apparent that the average skin-color of all the children was about the same as the average color of the parents of those children. As a next step in analyzing the data, the readings for skin-color of the individual members of the numerous families in the series were inspected one by one. And we found that in none of those families was the lightest child significantly lighter in color than his lighter-colored parent; in none of them was a child significantly darker than his darker parent.

The meaning of this, in terms of the tales of "black babies" born to seemingly white parents, is clear; it means that there is no foundation for such stories. Every tale of this kind which, to my knowledge, has been traced to its source has resulted in the discovery that there is not only the possibility, but often the strong probability, of more Negroid parentage of the "black" child than would be assumed on the face of the report. All scientific evidence goes to indicate that even where both parents have a slight degree of Negroid ancestry, the chance of the appearance of such a child is highly remote. True, the child might possess slightly crinkled hair, but who has not seen persons of unmixed European descent with such hair? Or his skin might be of the color we call "swarthy," or his lips be those we term "full" in contour. But for the child to be Negroid in the sense that a person of one half or even one quarter Negro ancestry is African-like, approaches the impossible when the parents are so

nearly white as they are in the cases that are cited.

There are, however, other problems than those of the "throw-back" and of Mendelian heredity in man which may be studied in racially mixed groups. What of the claims that race-crossing leads to a loss of vitality, to degeneracy? Or, on the other hand, that mixture gives new vigor to the offspring? There is not enough scientific evidence to support either position; in the main, it appears that it is the ancestral stuff that has gone into a person, rather than the racial types from which he has descended, that makes him what he is, and the same would appear to hold true for entire peoples.

Two of the most mixed groups that have been studied show no lack of vitality, for the average number of offspring of a Bastaard mating is 7.7 children, while among the Pitcairn Islanders there are persons who have attained the ages of 73, 87 and 95. It would be as well to argue that the present condition of the racially pure Tennessee and Kentucky mountaineers is due to the absence of crossing, as some have actually maintained, as to argue that racial mixture, as such, has caused the lowly state in which many mixed populations are found.

That race-crossing, then, does not of itself make for either good or evil results in the offspring would seem to be a tenable conclusion. For the student of human heredity, the value of racially mixed peoples lies in the fact that from the study of such groups the story of the processes of human heredity will eventually be wrested.

BEE BEHAVIOR

By JAS. I. HAMBLETON

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THE honey-bee is often referred to as a domesticated bee, and is thus placed in a class with our domesticated farm animals. The truth of the matter is that the honey-bee is far from being domesticated. Apparently it is as wild to-day as it was centuries ago, and this in spite of the fact that man and bees have been closely associated since the dawn of history. Other wild animals that our early ancestors sought to tame and domesticate have yielded to man's influence, and many of them in turn are now as dependent upon man as man is upon them. The honey-bee, however, shows no change as the result of its long association with the human race.

There are no domesticated bees. The bees that inhabit picturesque countryside apiaries are as wild as the bees found in a bee-tree in the densest part of an isolated forest. Bees taken from a bee-tree and placed in a modern hive are at once just as much at home as if they had always lived there, and *vice versa*. If a swarm of bees departs from a modern apiary and seeks its abode in some hollow tree, it is able to fare as well as any of its ancestors that knew no habitation other than hollow trees and caves.

Before explaining why the bee has not been tamed or domesticated, I must tell you something about the make-up of a colony. Ordinarily a colony consists of from 30,000 to 80,000 individuals. Of this number several hundred may be drones or male bees. The drones are unable to gather their own food and, having no sting, they can not defend their homes. Their only function in life is that of mating, and, incidentally, the

drone dies immediately afterwards, a sacrifice to perpetuate the race. Heading the colony is one queen, who likewise has but one function, that of egg-laying. After a queen mates with a drone, she returns to the hive and never again leaves it except at swarming time. She has no responsibility other than egg-laying, and this she does quite well, being able to lay as many as fifteen hundred eggs a day and to keep this up for days at a time. After laying the eggs she gives no further thought to her growing family. The queen takes no part in feeding the young and never once goes to the field in search of nectar or pollen. The remainder, and most numerous part, of the colony is made up of worker bees. These are females who lack the power of reproduction but have assumed all other maternal instincts. They feed the queen mother and their worthless brother drones; they take care of the young; they keep the hive spotlessly clean; they secrete the wax with which to build comb; they toil ceaselessly in the fields in search of pollen and nectar. When gathering nectar and pollen, these worker bees perform an inestimable service to mankind, for our orchards would bear little fruit were the honey-bees not on hand to cross-pollinate the blossoms. In addition, the duty of defending the hive falls to the lot of these daughter bees, and this, as we all know, they can do quite expertly, since each is armed with a sting sharper than the finest needle.

To go back to our reasons why the bee has not become domesticated. The queen and the drone are the only individuals in the colony that have the power of reproduction, but neither has any contact with the outside world. Their work never varies; they do not have to buffet against all kinds of weather conditions; they take no part in defending the hive. In other words, they are not subjected to many new experiences. The worker bees, on the other hand, are subject to a world of new experiences and new conditions, but, since they have no offspring, it is impossible for them to pass on to future generations the benefits of these outside experiences. With practically all other animals, as well as plants, the individuals that are subject to changing conditions and to new experiences also possess the power of reproduction and will pass on to their offspring in small part the benefits of acquired characteristics. Furthermore, man has been able to control the mating of most animals and plants. The queen bee, however, mates only on the wing while high in the air. Attempts to control mating by confining queens and drones in cages or allowing them to fly in large greenhouses or other enclosures have failed. Consequently, man has not been able to bring about changes that he might have done had he been able to control mating. Only within recent years has it been possible to control the mating of queens and drones. Work of this type in which instruments are used to impregnate queens is now being done by the Department of Agriculture and by other research institutions, and we can reasonably expect that in time some changes will be brought about in honey-bees, making them still more useful.

In spite of the fact that the bee has not been tamed, it has been possible, through a knowledge of its behavior, to make it amenable to human needs. The modern beekeeper, for instance, who is able, in a location where honey plants abound, to produce as much as 200 pounds of honey per colony in a period of three or four weeks makes no attempt to train his bees. On the other hand, he loses no opportunity to learn what he can of their behavior and to adjust his practises accordingly.

The modern beekeeper knows that the average life of the worker bee during the active season is only six weeks. The first two weeks the bee spends in the hive attending to household duties, and the

other four it works in the fields. Since there is no occasion to open a hive more frequently than once a week, the beekeeper is well aware that the bees never come to know their master. One who understands the behavior of bees can work in another apiary just as safely and profitably as in his own. We can, therefore, dispel at once the prevalent idea that a beekeeper does not get stung because the bees know him. Every person who has occasion to work with bees will be stung more or less frequently, and it is doubtful whether there are any persons for whom the bees have an inherent antipathy and whom they delight to sting. The layman who is stung most is probably the one who is most nervous and afraid of the bees.

The honey-bee is the only one of the common bees that loses its sting in an effort of defense, and in losing its sting the honey-bee also loses its life. The sting becomes so firmly anchored in the flesh that the bee can not free itself, and in trying to tear itself away it is injured internally to such an extent that it dies a few minutes afterward. Thus it is probably safe to say that there is not a honey-bee alive that has ever stung a human being. None of the honey-bees now in existence have ever had any previous experience or practise in stinging; yet each instinctively knows how to use this very effective weapon of defense.

Always about the hive are a few bees that assume the duty of defending it, and in performing the duty of plunging its sting into an enemy a bee sacrifices its life for the welfare of the colony. The assignment of this duty of defending the colony to only a few bees is a wise provision of nature. If all the bees in a hive rushed out in defense and were successful in stinging their victim, the colony would die. The beekeeper knows this, and he knows that he can disarm the guards with a little smoke and by judicious handling. He can, therefore, safely open a hive and with his bare hands remove frame after frame with thousands of adhering bees. If he accidentally crushes a bee, he will be stung. It is not uncommon also for a guard bee suddenly to go back on duty, and it will as readily sting the owner as it would the most casual stranger. Away from the hives, bees can scarcely be induced to sting. If you picked up a bee from a flower and held it in your cupped hands in such a manner that the bee could not escape, yet gave it room to walk about, it would make no attempt to sting. If you crushed it, of course, the story would be different. Ordinarily the honey-bee stings only in defense of the colony; it does not sting in its own defense, since to do so means its death. This is not true of other bees. Bumblebees, wasps, hornets and yellow jackets sting not only in defense of the colony but in self-defense, and they can sting, not once, but many times; neither do they lose their life by doing so.

In closing, just a word about the work of bees. Although no careful census of the bee population of the United States has ever been made, it is safe to assume that during the active season there are upwards of 280 billion honey-bees hard at work. At the end of the season they will have produced well over 150 million pounds of rich, mellow honey and about three million pounds of fragrant beeswax. Their greatest work, however, is in the cross-pollination of our fruit and vegetable crops. Their activity results in larger and more perfect crops. They even deserve much credit for helping to maintain our huge dairy industry by perpetuating the plants that grow in our pastures and meadows. Agriculture is heavily indebted to the honey-bee. Even religion owes a debt of gratitude to this industrious insect, since it makes possible the beeswax candles that light our cathedral altars.

NEW INDUSTRIES FOR OLD

By Dr. E. R. WEIDLEIN
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THE science of chemistry is essentially a nineteenth century development. Knowledge had accumulated through the ages from various practical sources—medical and metallurgical—but it was the quantitative interpretation of the atomic theory that made the relationship of elements and compounds intelligible and raised chemistry to the level of an organized science. This led to what is known as the scientific method of approach to the solution of problems. All preceding practise was altered by developing and perfecting a mode of attack by which men could undertake to solve problems, not by theorizing and speculating about them, but by theorizing to a point and then testing the theory under definitely and positively controlled conditions. In the main these experimental control tests do not have for their object the creation of new things, but rather a production of those new foundations on which new things can with certainty be created. However, the industries, in order to make use of this new knowledge, took into their ranks groups of men who were familiar with these new scientific developments. This was the beginning of our industrial research laboratories. Greater possibilities opened up for the scientist, and the result is seen in the enormous achievements that have taken place in the past thirty years.

The electric illumination, electrochemical, telephone, radio, automobile, airplane and metallurgical industries have been created from their basic inventions to important places in our present industrial organization during this period. It is significant that the time lag in the development of these industries has been greatly reduced by systematic scientific research.

Our knowledge is still primitive, and in some cases, such as in the field of electricity, we have incomplete information and can only describe such things as properties and behavior. It is not necessary to consider such complicated subjects here. Let us, instead, look at water, which every one knows as H_2O, and which contains two atoms of hydrogen and one of oxygen. Within the past two years, the chemists have discovered that pure water, which had always been considered a single substance, actually contains about one part in five thousand of a heavy variety of water, due to a type of hydrogen that is twice the weight of ordinary hydrogen. Heavy water is now being prepared in the laboratory, and it has physical properties strikingly different from those of ordinary water. It freezes at thirty-nine degrees instead of thirty-two degrees Fahrenheit. Certain plants and fish placed in concentrated heavy water have been unable to survive. On the other hand, it has been discovered that many growing things appear to have a slight preference for heavy water. This heavy hydrogen can be separated from the oxygen, and it is bewildering to think of the possibilities of substituting this new hydrogen in the thousands of compounds that contain the ordinary hydrogen, and as to what the results will be.

But leaving to one side these future possibilities and looking at present-day accomplishments, we find that none of our factories can operate without chemicals. Already it is possible to foresee some of the economic effects of a more thorough chemicalization of industry.

The effects would appear to be constructive. We do not have to speculate, for example, upon such fundamental facts as lower costs, which lead to higher consumption. Furthermore, technologic progress means on the one side higher obsolescence and on the other the creation of new industries.

It is generally recognized that industrial research is a factor in the unemployment situation: this research has often demonstrated that it is capable of bringing new employment and that it can compensate for the displacement of employment in other fields resulting from increased mechanical efficiency or other technical changes.

The cooperation of science with the industries has been directly responsible for our higher standard of living. We can not only maintain our present standard of living, but we can progressively improve this standard by creating the proper conditions for the industries, whereby they can plan for the future, and show the way by going ahead with the development of products and expanding activities, offering the consumer new and improved products at lower cost.

The chemical industry as a whole has maintained its research activities, has improved its manufacturing processes and the quality of its products, and has developed new and useful products, many of which will be offered other industries for rehabilitation. The recent improvement in the manufacture of phenol, making it available at a much lower cost, has stimulated the synthetic resin industry. The invention and technical development of synthetic resins constitute one of the outstanding achievements of industrial research. These resins not only equal but in many cases excel the natural products. Moreover, very large quantities of resins are required to satisfy the needs of the industries, and the natural sources of supply of these materials are by no means abundant. Resins are extensively used in paints, varnishes, linoleum, oilcloth, and in the electrical, radio and automobile industries. The molded material is now being developed for the building trades. The success that attended the molding of large size panels has led to the construction of a three-room apartment utilizing the vinylite-type resin. Everything in the entire apartment, with the exception of the plumbing fixtures, furniture, gas stove and the bathtub, was made of the resin. The walls, ceilings, floors, doors, moldings and baseboards were also made of vinylite. The illumination is transmitted through translucent sheets which have a light transmission efficiency of more than 90 per cent. Even the windows are sheets of transparent vinylite. The various towel racks, grab bars in the bathroom, door knobs, electric switch plates, as well as the cups, saucers, pitchers, tumblers and trays in the kitchen cupboard were molded from the same material. This extends even to the ornaments, cigarette boxes, ash trays and lamp shades.

This apartment was built solely as a means of demonstrating the possibilities of using resins for architectural construction, with no attention at the moment to the economic problems involved. It is of interest that the more the project is studied the more feasible it becomes from this standpoint. One firm has already entered the field to produce doors from this material, and it is likewise being used for panelling rooms and offices.

Such comforts and conveniences as we enjoy in our homes to-day are just the beginning of what the future holds forth. Research in the fields of lighting, heating, ventilating, air conditioning, as well as all types of new building mate-

rials, will make the home of the future to the home of the present what this year's latest model motor is to the horse and buggy of forty years ago.

Synthesis of materials is merely at the threshold of its service to mankind. It is the one means for man's protection when natural supplies fall short. The records of the synthetic camphor industry show that the markets have been greatly extended with a constantly decreasing cost to the consumer and with the prevention of a monopoly as occurred in the past, owing to the limited supply of the natural product. Another new product of this class, synthetic rubber, may in time have a very important bearing on the future price of rubber.

It is commonly thought that the chief aim of the scientist is to imitate vital processes, that is, to synthesize naturally occurring substances of the animal and vegetable kingdoms. However, the most valuable type of research, from an economic standpoint, is related to the utilization of certain of nature's products, such as coal, natural gas, petroleum, cotton, wood, corn and the like, as raw materials for making commercially new and valuable commodities by synthetic methods.

Modern civilization rests largely upon coal and iron, which in turn are linked by coke. In making coke, other materials, termed by-products, are had from which modern chemistry has developed thousands of very useful chemicals, fertilizers, explosives, disinfectants, perfumes, roofings, wood preservatives, medicines, photographic materials and practically all the dyes used in the textile industry.

The revolutionary changes in the paint and varnish industry to meet the demands of a better finish, and one that can be applied in a shorter period of time stimulated the development of new synthetic solvents. Thus came the lacquer industry of to-day. This advance, in turn, has created two other new industries. One of these is based upon corn as a raw material. The second depends upon natural gas and crude petroleum, and has developed into one of our largest chemical industries. It has made available in large quantity and at a low cost a variety of commercially valuable organic chemicals distinct in origin as well as in application, from the synthetic chemical products previously on the market.

Equally valuable with coal and petroleum as a raw material is cellulose. Rayon, born of chemistry, is based upon cellulose made from wood, cotton or other vegetable sources. Many manufacturers are at present making all-rayon fabrics, while others are combining rayon with cotton, silk or wool. Cellulose is also the basis of another new industry developed in the laboratory, the production of artificial sausage casings. Several hundred miles of these casings are now being made daily to cover our well-known "hot-dogs" and other meat products. As is so often the case in the synthetic manufacture of a new product, novel properties are introduced which give added value to the material. It is possible to remove these synthetic casings from the meat after the stuffing process, and the finished wiener is sold as a skinless product.

The scientific development of new products has great merit as a beneficial business force. Commercial changes occur constantly and inevitably and hence there is the correlative necessity for continuous product development to keep abreast or ahead of market requirements as well as competition. Constantly and endlessly, new and more attractive commodities are being produced by research, which also yields new uses for old products.

A new leather has recently been produced by making radical changes in the

tanning process. The leather is impregnated with materials that not only give support to the fibers but also lubricate them, providing for decidedly longer life against breakdown from flexing. The new leather can be obtained in any color; it increases the beauty of colored leather, giving a fuller and softer tone; its resistance to scuffing is greatly increased, and the presence of the lubricants permits renewing of the finish by brushing without the use of polishes.

A new method of bonding, employing a relatively soft metal as an adhesive, has been developed for the attachment of fibrous materials to steel. The fibrous material, which may be felt, paper or cloth, may then be saturated with any suitable substance, such as asphalt, oil or resin, to produce a waterproof and corrosion-resistant covering. After saturation, additional layers for protection or decoration may be applied by the use of paints, lacquers or synthetic resins, and by laminating operations with wood veneer. Many industries are now carrying on concurrent research on this product, in order to determine how it will fit into their particular manufacturing processes.

The story of the technical development of sodium hexa-metaphosphate, from a laboratory curiosity to a commercial product, in the past five years, is one of the romances of modern industrial science. Its first application entered in the treatment of boiler feedwater to prevent scale. It is now finding wide application in the laundry industry. The action of this chemical on lime soaps is in effect a "regeneration" process in which the soap, previously inactivated by the hardness of the water, is restored to its original activity, thereby effecting a saving in the amount of soap required and preventing the precipitation of a scum of alkali-earth soap with its impounded dirt. It is likewise being used in dish-washing, for cleaning shrubbery and as a pet wash. After rinsing with the metaphosphate solution, the textiles and also the fur and skin of animals are apparently cleaner than after washing in the usual way with soap alone. This is a good example of a laboratory product known for one hundred years that has just recently been put to work for the benefit of mankind.

The boundless importance of good air and ventilation, smoke and dust abatement, safe water and pure foods has impelled a great number of scientists to attack the many problems of personal and communal hygiene that arise from the use and abuse of these vital essentials. The scientist's view is really a plea for the more earnest application of science in the attainment of a greater measure of happiness, health and wealth. The spirit of all industrial research is sincerely scientific. It seeks to be open-minded toward new truth. It recognizes the intricacy of its problems; it does not hesitate to admit ignorance nor to suspend judgment. Its constant aim is the discovery of truth and its application to human needs. Its principal doctrine is the creation of new things rather than to concentrate thought and effort upon dividing existing things.

Every economic system is predicated upon two basic conditions. The first of these is human nature, because human wants constitute the dynamic force that drives the economic machine under the guidance of human hopes and human plans. The second is "the state of the art," the art in this case being the sum total of all ways and means, both physical and social, which man has at his command to make life on this earth more safe, more comfortable, more enjoyable.

CAN YOU LIVE WITHOUT WATER?

By ABEL WOLMAN

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BYRON many years ago in his "Don Juan" said, "Only the parched feel the agony of the desire for water." When President Roosevelt made water supply the principal topic of his recent speeches in the Far West, it was largely because the drought of present and past years has made our people water conscious. Only by chance has shortage of water reached international importance simultaneously with the economic depression, and it is again only by chance that newspapers debate the causes and effects of droughts in competition with the pros and cons of the NRA.

In peace time or, to continue our analogy, in normal times the water supply is in the silent service of public life. It then receives little attention either in the political or the economic arena. Unlike other phases of our existence, however, it is not easily controllable by acts of Congress. Even successful operation of the NRA can not prevent the unfortunate and horrible results of a lack of water supply. Fortunately, however, the results of the acts of God which lead to water shortage are subject to advance control by the development of more complete sources and their more adequate storage. During a drought we should give attention to the preparation for its recurrence. The lessons of to-day may be most helpful in preventing the calamities of the future. Our memories are short, however, and that is why we must hammer home now the elementary features of water supply provision, which with the ample rains of to-morrow will soon be forgotten.

The raw material for a water supply has only one source. It is the rain from heaven. It is neither inexhaustible nor ever-present. Unlike other raw materials, we can not live without it, if it were suddenly removed from the earth. In the past we have been threatened with the exhaustion of some important raw materials, such as iron ore, coal, oil, etc. Although their disappearance might cause considerable hardship, substitutes therefor or modifications of our living without them could result. When it stops raining, however, our raw material disappears. Unless we have been provident in conservation there is no answer to life unless it starts to rain again within a few days.

Most of us have probably forgotten what life was like when water was sold in San Francisco in 1865 at $1.00 per bucket. We are reminded, however, that this can recur even to-day, when whole communities in the Middle West were dependent for their existence, during the drought, upon water brought in each morning in railroad tank cars. All over the world for the last few years this amazing deficiency of water supply has persisted. People on rations are water conscious to a degree unbelievable ten years ago. Ingenious devices for conservation of waste water in England, Italy, France and the United States appear on the front pages of newspapers.

Water, like many other raw materials, occurs in different parts of the world in different amounts and in varying quality. In some countries rainfall is so copious as to be almost a nuisance, while in others its occurrence is so rare as to be hailed with amazement when it appears. In Cherrapunji, India, for example, the average rainfall in a year is over 400 inches, almost ten times that which occurs in New York City. In Yuma, in the desert of the United

States, less than one one-hundredth of this amount falls in an average year. As a matter of fact, in 1928, 0.47 inch fell in the entire year at Yuma. Obviously, if life must exist either in this Indian area or in this American desert, the calamities of too great or too small a quantity of annual rainfall must be considered. When we add to these difficulties of quantity the varying quality of this raw material, we begin to have some conception as to what it means to provide people with water.

In the first place, how much of this raw material do we actually need? A newspaper headline of a week or two ago states that one billion gallons of water a day is not enough for New York City. The city fears a salt-water diet for a million and a half people in spite of its gigantic reserve water supply. The British troops of General Allenby, on the other hand, in their forced marches against the Turks, used as low as one pint of water per man per day. The amount of water which a man uses depends primarily on how abundant it is and how cheaply he gets it. The subsistence demand for water supply, if we may so name man's metabolic requirements, is remarkably small. It is probably less than two gallons per person per day. But people use far more water than the bare subsistence demand would indicate. They have, in addition, a sanitary demand, an industrial requirement and what we may properly call a "luxury requirement." When times are good, people in every western country use more water proportionately than when times are bad. Presumably in periods of prosperity standards of living are improved and per capita water consumption increases. When wages drop and employment decreases, corresponding declines in water supply use occur.

Water supply consumption in the United States, greater than in almost any other country in the world, approaches the luxurious uses of the early Roman empire. Some people say this is an indication of the usual waste in the United States, but it is more probably due to a higher standard of living and a higher demand for sanitary equipment in this than in other countries. The average requirement for water supply in the United States is usually about 100 gallons per person per day. In German, British and French cities it is usually less than 50. In Holland it is less than 40 and in Italy less than 30 gallons per person per day.

When we compare the uses of sanitary facilities in various countries, however, we are led to conclude that the requirements for water, made necessary by a wider distribution of sanitary facilities in the United States, represent not an illegitimate wasteful use, but probably a legitimate necessary sanitary demand. How can you decide whether or not an average daily per capita use of water of 400 gallons in Beverly Hills, California, is an illegitimate use or an evidence of a perpetual orgy? It is easier to believe that, because Beverly Hills has large estates, private swimming pools, well-cultivated lawns and private houses with three to five bathrooms, it is really a legitimate consumption. These figures give some indication, however, as to the amount of raw material which must be provided in some fashion or other in order to make it possible for our urban and rural communities to survive.

Once we guarantee the vast amounts of water necessary for the continuance of domestic and industrial life, we must concern ourselves with the manufacture of a final product which meets the requirements of the average citizen. His requirements have changed to an amazing degree in the last quarter of a century. There was a time when the citizen was willing to drink anything which

flowed. In the Southwest it was frequently said in the nineties that water was squeezed out of the mud rather than the mud removed from the water. As esthetic standards became more rigid, however, the American consumer began to require a water which was clear to the eye, attractive to the taste and smell, safe from the public health standpoint, noncorrosive to the plumbing system, soft for the laundry and satisfactory for the steam boiler or other industrial use.

This requirement for improved quality in every direction has made it necessary to treat water in a variety of ways. To-day this raw material is subjected to settling, to coagulation with a variety of chemicals, to sand filtration, to treatment with chlorine, to removal of carbon dioxide, iron, manganese and to water softening. Perhaps one of the largest industrial processes in operation in any community is the one for the fabrication of a safe and palatable drinking water. It is the one, incidentally, which is least popularized by the local chamber of commerce.

When it has been produced, its delivery to the consumer is further safeguarded. Obviously it can not be wrapped in Cellophane as are many other less important products, but it is delivered through thousands of miles of pipe lines and is protected at every exposure by continued and eternal vigilance by various public agencies, until it reaches the water tap.

The man who turns on the faucet at any hour of the day or night expects a clear, limpid, safe, non-corrosive, soft liquid to flow in unlimited quantities and, therefore, never worries much about the origin of this life-giving fluid, its conversion into a satisfactory product or its cost. He paraphrases the comment of the originator of the first public water supply in Philadelphia, Benjamin Franklin, who said, "When the well's dry, they know the worth of water."

One of the remarkable facts about this unfamiliar industry is that its product is one of the cheapest commodities made in the United States. Water costs about 5 cents a ton, meat about \$500 a ton; bread, \$150; milk, \$120; gasoline, \$40, and coal, \$5 per ton. And, incidentally, this cheapest commodity of all, when properly conserved, may meet your requirements for centuries to come. It requires only vision and good sense to make it permanently available. Water shortages due to droughts are confessions of unpreparedness. "In time of peace prepare for war" may, without criticism from any pacifist, be converted into the slogan, "In time of rain, prepare for drought."

EVOLUTION OF A MODERN DEFINITION OF THE MATHEMATICAL TERM "GROUP"

By Professor G. A. MILLER
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THE gist of the notion of a mathematical group may be expressed as follows: A mathematical group is a set of distinct elements which obey the associate law when three or more of them are combined and are closed with respect to the solution of linear equations in the form $ax=b$. Nothing is said in the definition of the term group as regards the law of combination of two of its elements except that only one element results therefrom whenever the order in which these two elements are combined is fixed, and, as there are only two such possible orders, no more than two elements can result from the combination of two given ones. As the combination of elements and the solutions of linear equations appear in the oldest extant mathematical literature the concept of group is connected with the earliest known mathematical operations, but it did not receive explicit recognition before the latter part of the eighteenth century and it was not recognized before the latter part of the nineteenth century that it permeates wide fields of mathematical development.

The term group was first used with a concrete mathematical meaning by E. Galois (1811–1832), but its general introduction as a mathematical term was largely due to the influence of C. Jordan (1838–1922), who employed it frequently in his classic "Traité des substitutions," 1870, and defined it, on page 22 thereof, as a system of substitutions which includes the product of every two of them. It was known long before this time that many other sets of elements, including the natural numbers, also have the property that they contain the product of every two of them, but no special term was employed with respect to these sets on account of this property until the term group had become somewhat popular in the writings on the substitution groups that can be constructed on a given number of letters. The question naturally arises why this special term was favorably received when applied to sets of substitutions, but no similar term was employed until somewhat later with respect to other sets of elements which also satisfy the condition that they include the product of every two of them.

The answer to this question seems to be that on account of other properties inherent in these substitutions it is possible to find a large number of theorems of general interest with respect to sets of such substitutions which satisfy the condition that they include the product of every two of them. It was later noticed that many of these theorems are not confined to sets of such substitutions but apply also to a much wider realm of ideas. This observation led various mathematicians, especially S. Lie (1842–1899) and F. Klein (1849–1925), to study other sets of elements, including transformations, which have the property that they include the product of every two of them. While the sets of substitutions on a given number of letters which satisfy the condition that they contain the square of every one and the product of every two must therefore include also the inverse of each of these substitutions and hence also the identity this is not true as re-

gards some of the more general transformations considered by S. Lie, F. Klein and others.

This fact did not at first lead all these writers to modify their definition of the term group. It did, however, lead S. Lie and others to confine their attention to the study of what they regarded as special classes of groups. In particular, S. Lie found it desirable to insist that the groups studied by him contain the inverses of all their transformations and therefore also the identity. Hence it is sometimes said that every Lie group includes the identity,[1] notwithstanding the fact that S. Lie explicitly said that the totality of the transformations of the form $x' = ax$, where a is a proper fraction, constitutes a group which involves neither the inverse of any of its operators nor the identity.[2] When it is said that every Lie group contains the identity it should be noted that this is true of those groups which are included in his general theory of continuous groups of transformations but not necessarily of some special sets of transformations which he and others then also regarded as groups.

In his well-known *Vorlesungen über die Entwicklung der Mathematik im 19. Jahrhundert,* Volume 1 (1926), page 335, F. Klein asserted that in the definition of group there appears the remarkable but typical phenomenon that also in such questions there has presented itself during the last decades a change from the intuitive active conception of things to an abstract formulation. When he and S. Lie undertook to develop the meaning of group theory for the various domains of mathematics they assumed that a group is the totality of single valued operations such that any two of them can be combined and give again an operation of this totality. In his further investigations of infinite groups S. Lie found it necessary to require that besides every operation of the group considered by him its inverse should also appear therein and hence also the identity, as was noted above.

In the evolution of a modern definition of the technical term group it is obviously important to notice the wide difference between the views of those who confined their attention to groups such that they include the inverse of every operator contained therein and of those who regarded this property as a part of the definition of a group. The fact that F. Klein had not adopted the latter view even as late as 1893 follows from a note to his now famous "Erlanger Programm," which he republished during this year in the *Mathematische Annalen,* Volume 43, page 66. He stated explicitly in this note that a group of infinite order does not necessarily include the inverse of every one of its operators, and the fact that he gave here S. Lie credit for having first called attention to this property seems to imply that he considered it then to be of considerable importance. In fact, it is a direct consequence of the unsatisfactory definition of the term group used by S. Lie and F. Klein up to that time and it is merely one of very many oddities admitted by this definition.

The year 1893 is also important in the evolution of a modern definition of the mathematical term group, because H. Weber published in the journal volume noted in the preceding paragraph (page 522) the earliest general definition of an abstract group, which applies to groups of infinite order as well as those of finite order. In particular, this definition includes the now widely used equational condition that if in the equation $xy = z$ two of the symbols are replaced either by the same operator or by two different operators of a given group then the resulting linear equation is satisfied by

[1] G. Kowalewsky, "Theorie der Kontinuierlichen Gruppen," 1931, p. 95.

[2] S. Lie, "Theorie der Transformationsgruppen," Vol. 1 (1888), p. 163.

one and only one of the operators of this group. H. Weber gave here also the postulate that the operators of a group obey the associative law when they are combined, but he failed to make it clear then that these two conditions are sufficient for a general abstract group. In his "Lehrbuch der Algebra," which he began to publish about two years later (1895), he modified this definition somewhat, but in his "Kleines Lehrbuch der Algebra," published in 1912, shortly before his death (1913), he used again this equational condition (page 181), and hence it seems to have been the result of mature considerations.

No other writer contributed so much as H. Weber towards the establishment of a widely accepted definition of the technical term group, but even he was not entirely successful in winning universal support. It is especially noteworthy that none of his definitions was adopted in the largest extant mathematical encyclopedia, which began to appear about five years after he had published his first acceptable general definition. This encyclopedia is entitled "Encyklopädie der Mathematischen Wissenschaften," and on page 218 of the first volume there appears a definition which is satisfied by the totality of the natural numbers which exceed an arbitrarily fixed one of them when they are combined either according to ordinary multiplication or according to ordinary addition, and hence it implies that a group does not necessarily involve either the identity or the inverse of each of its operators. This is the more remarkable since H. Weber was one of the collaborators of the first volume of this encyclopedia, writing the article on complex multiplication, and he was then representing the Deutschen Mathematiker-Vereinigung on the committee of publication. He was also professor of mathematics at the University of Göttingen (1892–1895).

We have thus far aimed to exhibit a few of the most outstanding features of the evolution of a modern definition of the technical term group, but various details need to be added thereto to give a clear picture of this evolution. Probably the most striking of these details is the rôle which A. Cayley (1821–1895) played in this evolution, since he was the first to formulate a definition of an abstract group of finite order. He did this in his first article on the subject of groups, published in the *Philosophical Magazine,* Volume 7 (1854), page 40, under the heading "On the Theory of Groups as Depending on the Symbolic Equation $\theta^n = 1$." In his numerous later publications on this subject he never again gave such a complete definition nor did he give any evidence in his later writings that he himself realized the importance of the step which he had taken in this first article on the subject. He thus naturally failed to be as influential in the evolution of a modern definition of the technical term group as one might at first be inclined to infer from his pioneering work along this line, but he deserves more credit for it than he has commonly received.

It is interesting to note that A. Cayley's definition of the term abstract group of finite order, which appears in this early article, is practically equivalent to the one formulated about twenty-eight years later by H. Weber[3] without giving any reference to any earlier formulation of such a definition. The postulates in the latter definition were stated more clearly than in the former, and it is not implied here that H. Weber was probably aware of the earlier work along this line when he published his definition. His postulates and those of A. Cayley were probably suggested by the theory of the groups on a finite number of letters, and hence their similarity

[3] H. Weber, *Mathematische Annalen,* 20: 302, 1882.

does not necessarily imply that the latter were based on the former. It is, however, true that A. Cayley failed to receive due credit on the part of various later writers on the subject who probably would have given due credit to him if H. Weber would have given the appropriate references in his publications on the subject.

Even as early as 1860 A. Cayley published an article on the term group in the "English Cyclopedia," in which he did not postulate even the associative law in the definition of this term. This is the more remarkable since he seems to have been the first to state this law explicitly in a definition of an abstract group, having included it among the postulates of a group in his first article on this subject, as noted above. As is well known, W. R. Hamilton (1805–1865) named and employed this fundamental mathematical law in other connections at an earlier date. The fact that A. Cayley was not steadfast in the use of some of the advances he had introduced makes it difficult to determine how much credit should be given him for these advances, since he himself seems to have failed to realize their importance. Possibly this is also true as regards his now famous dictum, "A group is defined by means of the laws of combination of its symbols," which W. Dyck put at the head of a very influential article, and thus won for it and its author wide recognition.[4] It represents an important step (1878) in the evolution of a modern definition of the term group.

A somewhat striking incident in the evolution of a modern definition of the term group is furnished by a set of postulates formulated in 1870 by L. Kronecker. This has been called the "first explicit set of group postulates" by E. V. Huntington,[5] although it was formulated in connection with the theory of numbers and relates only to abelian groups of finite order. It is especially interesting because it exhibits close contacts between abstract group theory and number theory since L. Kronecker was concerned here with some underlying principles of the latter subject. About the beginning of the present century various sets of postulates for an abstract group were formulated by several American writers, including J. Pierpont, E. H. Moore, E. V. Huntington and L. E. Dickson. These writers were then mostly concerned with the best possible form in which such a set of postulates can be presented and with the question of the independence of these postulates. In content they did not aim to deviate from the sets of postulates announced earlier by H. Weber, and their writings helped to make these postulates better known.

E. V. Huntington stated in this connection that he himself seemed to have been the first to study sets of group postulates with respect to the question of their independence, and this represents a final theoretical step in the evolution of a modern definition of the technical term group. In speaking of such postulates F. Klein remarks, at the place to which we referred above, that the appeal to the imagination is thereby fully removed. In place of it the logical structure comes to the forefront. The abstract formulation is excellent for the development of proofs but is not well suited for the discovery of new ideas and methods. It rather presents a termination of earlier developments and hence it simplifies instruction, since one is able to furnish thereby complete proofs of known theorems. This has always been an important function of systems of postulates.

Although the evolution of a modern definition of the technical term group may be said to have been theoretically completed about a quarter of a century

[4] W. Dyck, *ibid.*, p. 1.

[5] E. V. Huntington, *Transactions of the American Mathematical Society*, 6: 181, 1905. *Cf.* G. A. Miller, *Science*, 79: 291, 1934.

ago, practical difficulties remained, and still remain, in view of the fact that many of the older and inadequate definitions have appeared in some works of reference which are highly regarded, and hence these inadequate definitions are frequently repeated in more recent publications. As an instance of this kind we may cite the statement that a cyclic group of infinite order has two independent generators, which appears, for instance, in such a favorably known work as Pascal's "Repertorium der höheren Mathematik," Volume 1 (1910), page 193. This statement is clearly based on the assumption that a generator of a cyclic group and its inverse may be regarded as independent, and hence that the inverse of an operator does not necessarily appear in every group which contains this operator. It would seem that the term group should now imply at least the existence of the inverse of each of its operators.

An example which has a somewhat striking history is the totality of the natural numbers when they are combined by ordinary multiplication. In the first edition of Volume 2 (1896) of Weber's "Lehrbuch der Algebra" it is asserted (page 54) not only that the natural numbers constitute a group when they are thus combined but also that this group is the most important example of an abelian group. This statement is corrected at the corresponding place of the second edition of this volume and deserves notice here mainly because the first edition of this volume is still widely used, and because similar statements are found in many other places. For instance, such a statement appears in the recent Italian "Enciclopedia delle Matematiche Elementari," Volume 1, part 2 (1932), page 43. Whether such a statement is correct or not depends upon the definition of the term group, and our main object here is to show that the recent tendency has been to give a definition of this term according to which these numbers do not constitute a group when they are combined by ordinary multiplication.

A more serious inaccurate statement appears on page 20 of the volume of the Italian encyclopedia noted above. It is here asserted that the notion of group has received a great extension during the last fifty years by including therein all the operations or transformations, finite or infinite in number, executed on the entities of a given field, whenever the transformation resulting from the successive application of any two of them belongs itself to these transformations. It should be observed that this is not in accord with the statement of F. Klein noted above, according to which during recent decades a change in the definition of group has taken place from the intuitive active conception to an abstract formulation. This abstract formulation required limitations so as to obtain a definition which can be used to develop an extensive abstract theory. Not a single one of the hundreds of theorems relating to the theory of groups could be proved if the extension noted at the beginning of this paragraph had actually taken place in abstract groups.

It should be observed that the postulates which underlie the modern term group belong to the category of the mathematical postulates which can be proved to be true for various restricted fields but are classed as postulates because wider fields are also considered in the general subject under consideration. In particular, the associative law can be clearly proved when we confine our attention to the permutations or substitutions on a given number of letters. In this respect the group theory postulates differ widely from those which can not be proved to be true, even for a restricted field, such as the parallel postulate in elementary geometry. One of

the singular facts in the history of mathematics is that before the first half of the nineteenth century no one seems to have realized the desirability of emphasizing the associative law, while now the freshman in our colleges is supposed to become somewhat familiar with it.

The totality of the natural numbers when combined by multiplication includes the identity but no other inverse of an operator contained therein. If a set of operators which includes the product of every two includes the inverse of at least one of them it also includes the identity. Notwithstanding this obvious fact, systems of postulates underlying a definition of the term group frequently include as two separate postulates the facts that the set of operators under consideration involves both the inverses and also the identity. This is done in particular in the system adopted by F. Klein at the place to which we referred above. It should therefore be noted that in the evolution of a modern definition of the technical term group emphasis on important facts seems to have often been given precedence over the question of logical independence of the concepts involved in such a definition. This may serve to explain why the question of this independence does not seem to have been explicitly considered before the beginning of the present century.

During recent years the mathematical term group has appeared in the scientific literature with increasing frequency and the inconsistencies in the use of this term have become more and more annoying. It may therefore be a timely effort to try to exhibit some of the sources of these inconsistencies in the hope that this will help to secure greater uniformity. While it is natural that the term group was used in the past with a variety of meanings and this caused comparatively little inconvenience as long as the number of those using it was small, the time seems to have come when greater uniformity in the use of this term is very desirable and it is hoped that an understanding of the steps towards an evolution of a modern definition of the term may be conducive to securing this uniformity. In the writings of such an eminent mathematician as F. Klein was one can notice the transition from a vague to a more nearly exact use of this term, and it seems possible that a similar transition can be secured in the public mind.

LIGHTNING DISCHARGES TO GROUNDED CONDUCTORS

By Professor J. C. JENSEN
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THE effectiveness of lightning rods and other grounded conductors in preventing discharges to buildings, trees, oil reservoirs and transmission-line towers has been the subject of much recent discussion and investigation. It is commonly believed that silent electrical discharges into the air from metal points, such as are found on lightning rods, equalize the difference of potential between the clouds and the earth, and thus decrease the danger of a lightning stroke in the vicinity. The fallacy in this argument lies in the fact that similar discharges escape from every tree in a forest, when a thunder-cloud is overhead; nevertheless, lightning does strike in the heaviest timber and cause many fires. Obviously a few metal points on a house can not be expected to do what hundreds of tall trees fail to accomplish. That properly installed rods do give protection by carrying lightning discharges safely to the ground is shown in figures compiled by the State Fire Marshal of Iowa, where 93 per cent. of the losses caused by lightning in 1919–1924 were in unrodded structures.

Transmission line towers, radio antenna, metal flagpoles and similar grounded objects have frequently been struck without material damage being done, as have also rodded smokestacks and projecting metal parts of brick and stone buildings with bonded steel framework. The 500-foot steel antenna towers recently erected for several of the high-powered broadcasting stations are all provided with safety gaps across the base insulators, and experience has shown that these gaps are often required to function. Researches of Schonland in South Africa,[1] of the present writer,[2] and of several American engineers all agree that such discharges usually come from a negatively charged cloud.

The old adage that lightning never strikes twice in the same place has been definitely disproved by repeated strokes to the well-known Empire State Building in New York City. About four o'clock on the morning of June 10, 1933, Mr. Henry A. Shimer, from his home at 340 West 55th Street, obtained five pictures of direct discharges to the mooring mast as shown in Figs. 1, 2 and 3. He witnessed another direct hit early in the evening of April 24, 1934, and got additional pictures of one during the storm of May 22, 1934. Eye-witnesses of the first of these displays state that the brilliant flashes were repeated about once per minute for a quarter of an hour.

The Empire State Building is 1,250 feet high, with steel framework, which is thoroughly bonded and grounded. The outer structure of the tower and the mast are also of metal. The building may, therefore, be likened to a gigantic lightning rod extending almost a fourth of a mile up into the air. Considering the high relative humidity in the vicinity of New York and the early summer season, it is probable that the base of the cloud was less than a mile above the

[1] Schonland, *Trans. South African Inst. Elec. Eng.*, Vol. 24, June, 1933, p. 148.

[2] J. C. Jensen, *Journal Franklin Inst.*, Vol. 216, Dec., 1933, p. 707.

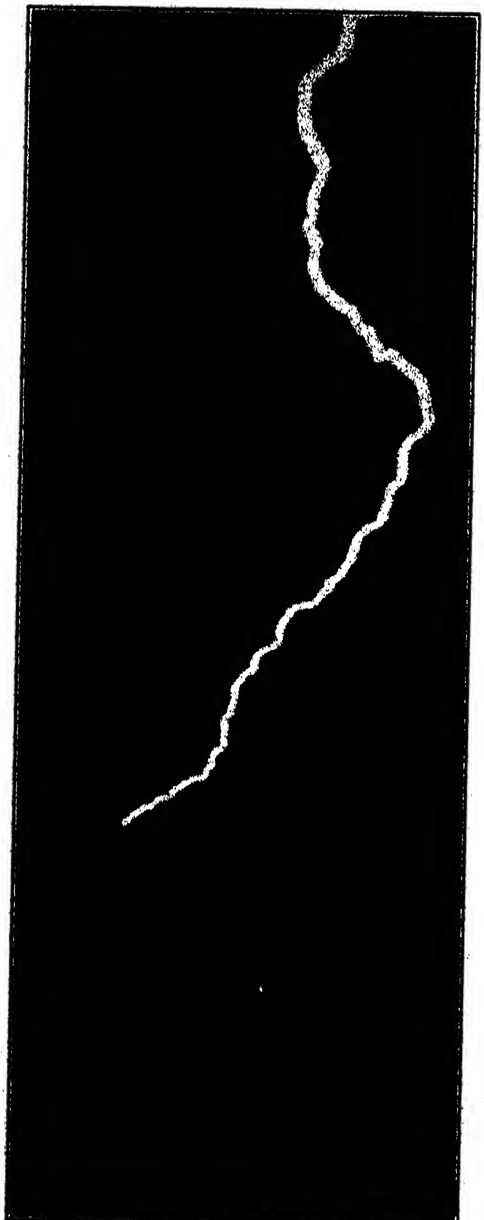

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FIG. 1

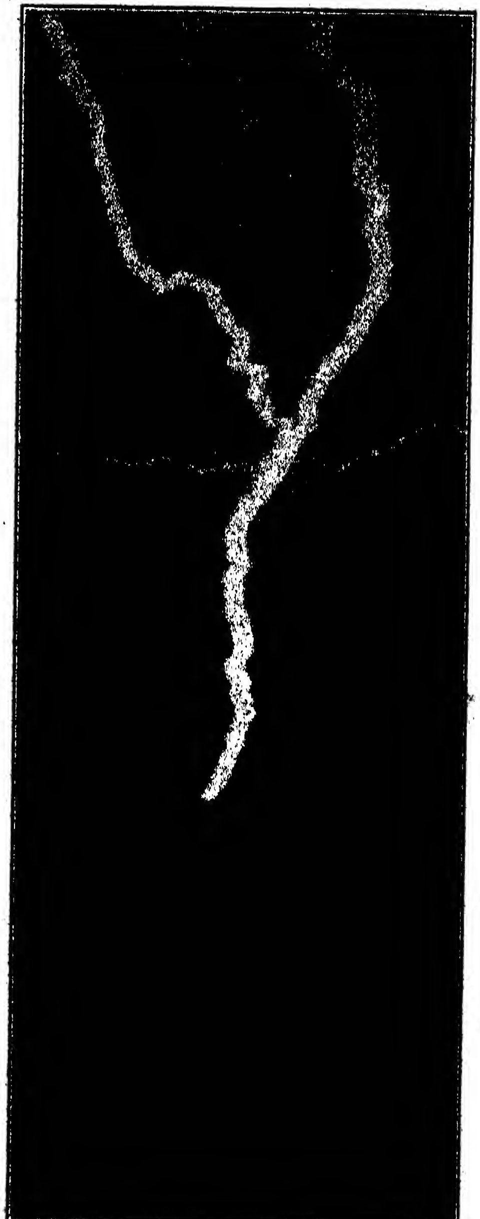

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FIG. 2

earth. The tendency for a thunderstorm which is forced up over a mountain to send numerous lightning discharges to crags and ridges is well known. In that case the cloud usually does not rise as rapidly as the mountain ascends, so that the distance from cloud to ground is decreased, resulting in a higher potential gradient between them. With a tall building on level ground, however, the

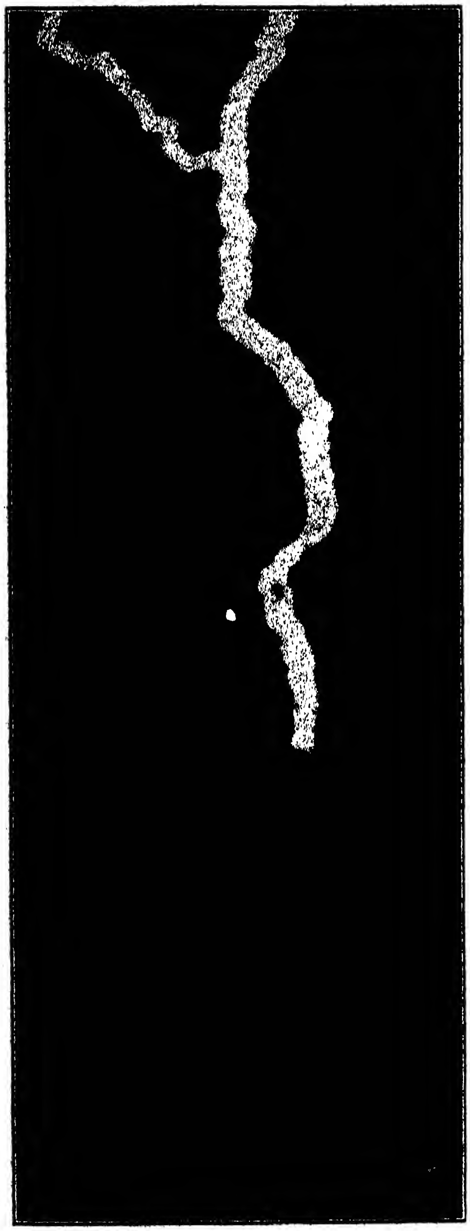

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FIG. 3

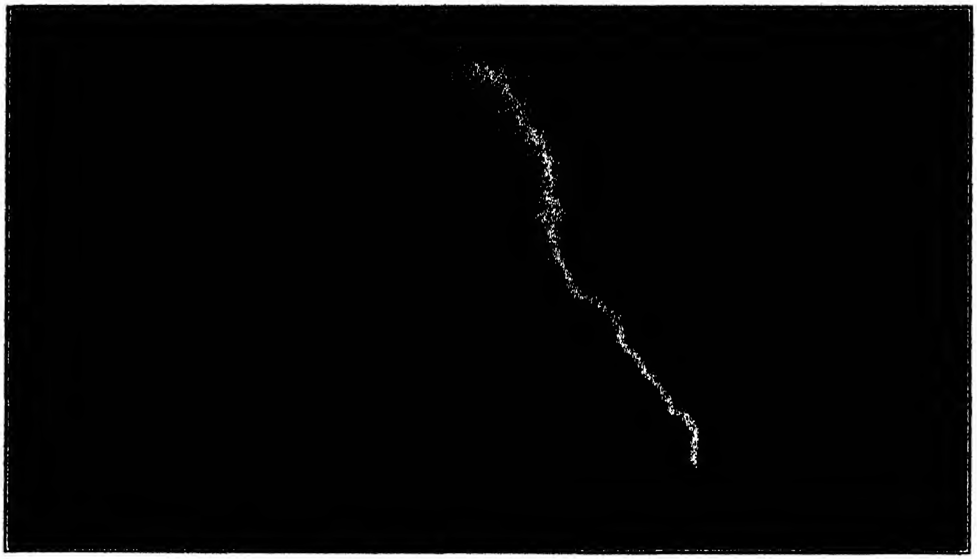
cloud configuration does not change and the increased potential gradient occurs only in the area immediately above the building.

In their South African studies of lightning discharges with special cameras equipped with rapidly moving lenses, Schonland and Collens[3] have shown that a stroke to ground from a cloud with negatively charged base consists essentially of two parts. Because of silent discharges of electricity from pointed objects on the earth a space charge is formed near the ground which reduces the electric field there. As a consequence the potential gradient is highest directly below the cloud and the first discharge consists of an electron avalanche of negative electricity from cloud to ground. In the second stage the slow-moving positive ions from the earth follow the heated, ionized channel already prepared for them from earth to cloud. Both phases, especially the second, ordinarily consist of a number of surges which follow each other in rapid succession. This has recently been corroborated by Lloyd and McMorris[4] at Pittsfield, Massachusetts, who used a special camera in which the film is drawn past the lens at the rate of a mile per minute.

Any one who has visited the observation tower at the top of the Empire State Building will be impressed with the unusual size of the lightning channels in the accompanying pictures. The upper part of the tower is 32 feet in diameter, so that the width of the channel in Fig. 1 must have been about 30 feet in its widest part, while that in Fig. 3 was more than 100 feet. These values are in agreement with computations based on the focal length of the lens used in Shimer's camera and his distance from the tower, *viz.*, 6,180 feet. As the result of researches conducted in recent years it is now certain that the earlier estimates of the current in a thunderbolt at 5,000 to 10,000 amperes

[3] Schonland and Collens, *Proc. Roy. Soc. A*, Vol. 143, 1934, p. 654.

[4] Lloyd, McMorris and McEachron, *Gen. Elec. Rev.*, Vol. 37, July, 1934, p. 349.



1930, J. C. Jensen

FIG. 4

were too low and that values of 50,000 amperes or more may easily be reached. The earth resistance in a modern steel building should be very low, since its foundations penetrate deep into moist ground and its water, gas and sewer connections constitute a veritable network of earthed conductors with branches ramifying in every direction. The path impedance of the stroke was also low in this instance because of the shortness of the distance from the cloud to the tower. Both of these factors would tend to increase the current and the intensity of the discharge. It should also be recalled that the channels as photographed are composed of a number of strokes following the same general path, but subject to varying deflections by the high wind incidental to the storm.

A marked peculiarity of this group of pictures lies in the fact that two of the five show upward branching at an altitude of 3,000 feet or 1,800 feet above the tower of the building. Schonland and Collens found only downward branching in South Africa, while the present writer in an extended research[5] found only eight with upward branching out of 185 pictures, Fig. 4 being a typical illustration of a discharge to ground from a cloud with negative electricity in its lower portion. Examination of the barograph and anemometer records obtained from the U. S. Weather Bureau at Battery Place and from the observatory at the *Daily News* office show that this storm was a double one and that the secondary storm, with wind velocities reaching a maximum of 52 miles per hour, was approaching at the time when the pictures were taken. In that case these violent discharges came from the concentrated negative charges in the front of a cloud such as that described by Banerji[6] at Bombay and frequently observed by the writer in Nebraska. They would thus constitute typical negative branching in accord with the

[5] *Loc. cit.*

[6] E. J. Banerji, *Phil. Trans. A*, Vol. 231, 1932, p. 1.

theory of Simpson, eminent British meteorologist.[7] A more probable explanation, however, is that two leader strokes from different parts of the cloud were attracted simultaneously by the high potential gradient above this tall building and coalesced on the way down.

Of possibly greater interest to the layman is the fact that no physical damage has been suffered by the Empire State Building as a result of these repeated and spectacular efforts of Thor and his thunderbolts, except a few scars on the metal covering of the dome caused by arcing. While hissing brush discharges have been observed by attendants in the tower when a storm is approaching, none of the occupants have suffered any inconvenience when the building was struck. In fact, its framework forms a shield which makes its interior an unusually safe place for those who have a fear of lightning, and its high projecting tower serves as a target for descending flashes, thus protecting other buildings within a radius of 500 feet or more. It further shows that while lightning may and does strike grounded conductors, no damage will result if the building or other structure contains metal leads of sufficient dimensions to safely carry the charge to the earth.

[7] G. C. Simpson, *Roy. Soc. Proc. A*, Vol. 111, 1929, p. 56.

THE PROGRESS OF SCIENCE

THE NOBEL PRIZE IN PHYSIOLOGY AND MEDICINE

THE Nobel prize in physiology and medicine has this year been divided into three parts and awarded to Dr. George H. Whipple, professor of pathology and dean of the School of Medicine and Dentistry at the University of Rochester; Dr. George R. Minot, director of the Thorndike Memorial Laboratory of the Boston City Hospital and professor in medicine at the Harvard Medical School, and Dr. William P. Murphy, of the Peter Bent Brigham Hospital and the Harvard Medical School.

Prior to last year this prize—the world's greatest scientific honor, with a value of about $40,000—had been awarded twenty-six times in physiology and medicine, but only twice in the United States, whereas it has been awarded five times in Germany, three and a half times in France and three times in Denmark. In 1912 it was given for the cultivation of tissues *in vitro* to Dr. Alexis Carrel, who a few years previously had been called from France to the Rockefeller Institute for Medical Research, and in 1930 it was awarded for work on poliomyelitis, human blood groups and serological specificity to Dr. Karl Landsteiner, who came to the Rockefeller Institute from Austria in 1922.

The prize was, however, awarded in 1923 to Professor J. J. R. Macleod and Dr. F. G. Banting, of the University of Toronto. It is of interest that their work on the checking of diabetes by the administration of insulin following preliminary laboratory experiments is strikingly similar to the present award for the checking of pernicious anemia by the administration of liver and liver extract by Dr. Minot and Dr. Murphy following laboratory work by Dr. Whipple.

The prize has now been awarded in the United States for two consecutive years. Last year it was given to Dr. Thomas Hunt Morgan, of the California Institute of Technology, not, however, for work that would ordinarily be classed under physiology or medicine, but for distinguished work in biology, especially for his study of mutations in the fruit fly Drosophila. The basis for the award this year is clearly described in statements prepared for Science Service by Dr. Whipple and Dr. Murphy. Dr. Whipple writes:

Unpredictable by-products of research in physiology are rarely brought to the attention of the layman. The studies which led to the appreciation of liver as a food to promote hemoglobin regeneration were taken up with no idea of any clinical application. We wished to find out how the body built up hemoglobin and what materials could best be utilized by the body.

These studies are still being carried forward to determine what elements of food are most essential to make new hemoglobin. Dogs are best suited for these studies and all work has been done on these animals. They are frequently used to standardize liver fractions to be used in the treatment of human disease.

Future progress in the control of other diseases can not be predicted with any certainty but if history has any significance it points to future by-products coming from investigations in the wide field of pure science which will enable the physician to bring under control still other diseases which afflict human kind.

It is never safe to state that any bit of accurate knowledge about body physiology is useless, for in the future some student may sense its application to the study of some particular disease state.

DR. GEORGE H. WHIPPLE

Progress is often made by way of detours which look very unfavorable at first.

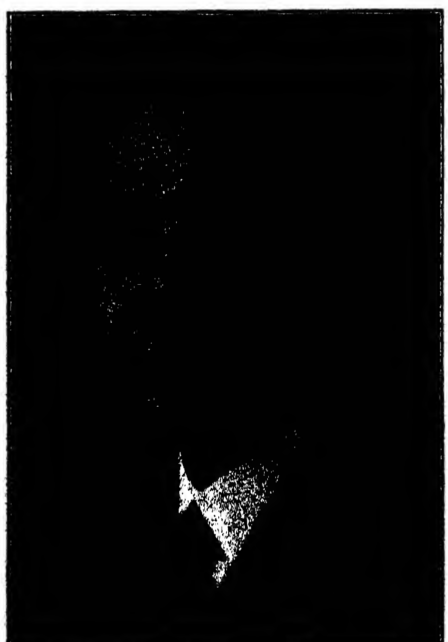
Dr. Murphy writes:

It gives me great pleasure to have this opportunity to briefly comment upon the work in which Dr. Minot and I have cooperated during the past ten years, and for which we have received the highest honor which it is possible for a physician to receive—awarded by the Nobel Prize Committee of the Caroline Institute of Stockholm, Sweden.

Since our initial work on the treatment of pernicious anemia by the use of liver, as carried out in our office practise and at the Peter Bent Brigham Hospital and the Collis P. Huntington Hospital in Boston, much progress has been made in the direction of improvement and simplification of treatment of the unfortunate victim of this disease.

Although the amount of liver necessary for each patient's needs may vary greatly it is necessary for him to take daily an average of from one fourth to one half pound, or during each month a total of eleven pounds in order to keep well. If instead of taking liver the patient is advised to take a potent liver extract by mouth it will be necessary to use daily three vials or doses and in a month eighty-four vials or doses in order to replace the effect of the liver. The average cost of eleven pounds of liver will be about $5.50, whereas the cost of the eighty-four doses will be approximately $17.00.

Contrast the difficulties and expense of such a regimen with that which is now possible through the development at the Peter Bent Brigham Hospital with the cooperation of Dr. Guy W. Clark, of the Lederle Laboratories, of an extract of liver which may be injected into the muscle and which is so concentrated that it is necessary to use only one injection to replace the eleven pounds of liver or



DR. GEORGE R. MINOT

eighty-four doses of liver extract if taken by mouth. And this concentrated extract for intramuscular injection costs but $1.20.

Is not such a saving worth while at a time when each and every one of us feels the need for the greatest economy? If one is to realize that treatment by means of this material costs even less than does the liver, is more effective in controlling the disease and is so much more convenient to take, I am sure that we can all agree that progress in the direction of simplification of treatment for patients with this disease is being made.

Let us consider the evidence that progress is being made in the control of this disease as judged on another basis.

The Metropolitan Life Insurance Company has recently compared the death rate from pernicious anemia for the period since 1926 when liver treatment came into general use with a like interval before 1926 when this treatment was not available. They observed that the death rate in individuals with pernicious anemia between the ages of 30 and 50 years has been only half so great since the use of liver as it was before. Above the age of 50 the death rate has not shown such a striking decrease, no doubt owing to complications which are more likely to occur during the older age period.

I feel sure that the death rate will be further reduced and that there need be no deaths from this disease if each patient will continue to take regularly in some form an adequate amount of liver substance as prescribed by his physician. The amount of liver substance necessary must be determined on the basis of regular determinations of the number of red blood cells and the patient's physical condition. It is our hope that even further progress in this direction will be made as others continue to take up the problem with us.

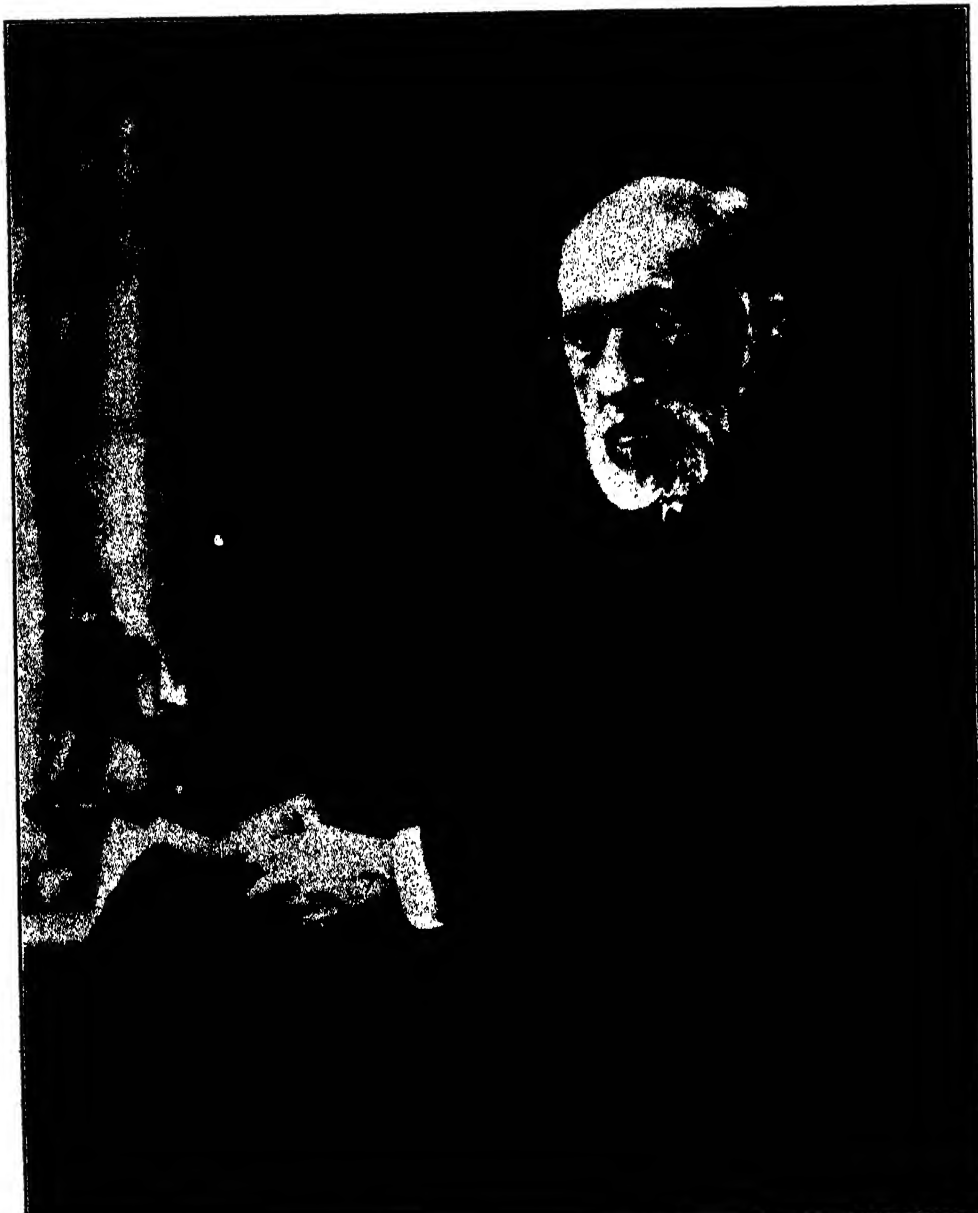
SANTIAGO RAMÓN Y CAJAL

(1852–1934)

A VERY great loss to science occurred on October 17 of this year when Santiago Ramón y Cajal, the great Spanish neurologist, died in Madrid. His death is a loss to the whole world, for wherever modern methods and procedures are followed the work of Cajal is known and honored, and his methods of studying the finer structure of the nervous system are used.

Cajal was born on May 1, 1852, in the village of Petilla de Aragon, in the province of Zaragoza, where his father, Justo Ramón Carasús, was physician and surgeon to the little community. Later, about 1870, the family moved to the university town of Zaragoza, where the son Santiago had already entered on the study of medicine. Here the father, in addition to his practise, gained the position of professor of dissection. He had a great enthusiasm for anatomy and he and his son dissected together for three years. At the end of his second year, on account of his industry and skilfulness, the young Cajal was given the position of *ayudante de disseccion*. After he had finished his medical course in 1873 and obtained the title of *Licenciado en Medicina*, he had to undergo his military service. For this he entered the Cuerpo de Sanidad Militar, and in the following year, 1874, was sent to Cuba with an expeditionary force. Here he contracted malaria and was in poor health until his return home in June, 1875.

For the next two years he studied intensively anatomy and embryology and helped his father in his clinical work. He was aiming for the doctor's degree, and in due time went to Madrid for his



THE LATE SANTIAGO RAMÓN Y CAJAL

examination. Here he was much impressed with the handsome histological preparations of Dr. Maestre de San Juan, and at once began to plan for a histological laboratory at Zaragoza. Soon after his return home an assistant in the department of physiology demonstrated to him for the first time the circulation of the blood. This event, Cajal tells us, roused in him an increased affection for microscopic studies. Soon he bought a new Verick microscope and a Ranvier microtome, partly with the money received as his military pay. A new world was now opened before him and he explored it with indefatigable zeal for over half a century.

In 1884 he became professor of descriptive anatomy at Valencia, and three years later professor of normal and pathological histology at Barcelona. In 1892 he was called to the University of Madrid as professor of pathological anatomy. He held this chair until he attained the retiring age of seventy, but continued as director of the laboratory of biological investigations (Instituto Cajal) until his death.

Cajal's most comprehensive work is his "Textura del sistema nerviosa del hombre y de los vertebrados." This was translated into French and published under the title, "Histologie du système nerveux de l'homme et des vertebrés," in two volumes, 1909–11. The translation was amplified in numerous places by Cajal so that it was in many respects a new work, with 925 original illustrations. In this book Cajal has given the results of his personal researches on the histology of all parts of the nervous system. One of the collateral factors in the success of the comprehensive survey which he was able to make was the choice of animal for the work. He made use of the mouse, one of the smallest of mammals, and by using the young of this form he was able to follow through all the structures of the brain in a comparatively small number of microscopic sections. Also, because of the contiguity of the various nuclei, he could often see nerve processes extending to their destination. Thus he was able to see the architecture of the mammalian brain more clearly than anybody had been able to see it before. Following him, many have investigated special parts of the brain, and time and again have verified his original observations.

Professor Cajal has provided us with a fascinating account of his career in an autobiography entitled "Recuerdos de mi Vida." Here he gives in vivid fashion the events of his early life, his education, the military expedition to Cuba, his aspirations and enthusiasms and also a good account of his achievements. Indeed the best introduction to Cajal's work is to study this survey which he himself has given us. In more than one hundred full-page plates, he shows us in chronological order the pictorial results of his numerous studies. Many of these are now to be seen in books of histology, anatomy, neurology, physiology and psychology, and indicate the widespread influence of his work.

He early found it necessary to have a journal in which to publish the results of the studies in his laboratory. While at Barcelona he began the *Revista trimestral de Histologica*. This ceased when he went to Madrid, and in 1896 he initiated the *Revista trimestral micrografica*. With Volume 6 the title was changed to *Trabajos del Laboratorio de Investigaciones biológicas de la Universidad de Madrid*. Since 1924 it has been published in French as the *Travaux du laboratoire de Recherches biologiques de l'Université de Madrid*. This journal contains the results of many brilliant studies by Cajal and his students, and is invaluable for following the advances in neuro-histology.

His honors were numerous. In the autobiography three pages are devoted to lists of distinctions obtained at home and abroad, prizes and medals, honorary foreign titles, and in a footnote it is stated that many others have been

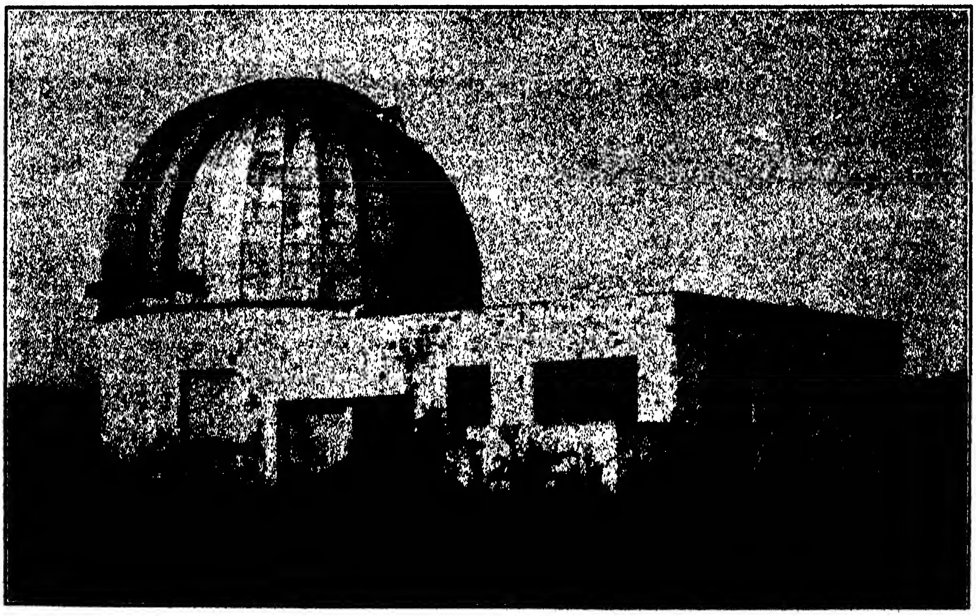
omitted for the sake of brevity. The best known is the Nobel prize for physiology and medicine, which in 1906 he shared with Camillo Golgi.

Perhaps the crowning event of Cajal's life, the greatest tribute to his work and to science in Spain, was the founding of the Instituto Cajal. When I studied in Madrid in 1928 this laboratory was still housed in the small but pleasant building which adjoined the Museo Anthropologico. On a height not far off rose the superstructure of the new Instituto, not then completed. Views of these buildings may be seen in the August, 1930, number of THE SCIENTIFIC MONTHLY. When I returned to Madrid in April, 1934, I found the new Instituto finished, a noble and stately building, well planned, with plenty of working space, good light and one of the finest special libraries to be found anywhere. It is true that the master's failing health made it impossible that he should spend much time in the new laboratory, but it was a great source of satisfaction to him to have the new Instituto Cajal completed during his lifetime, and to know that there his work would be carried on.

WILLIAM H. F. ADDISON
UNIVERSITY OF PENNSYLVANIA

OBSERVING AT THE NEW PRINCETON OBSERVATORY

THE 23-inch lenses removed from the old telescope tube in the Halsted Observatory nearly three years ago have been placed in the big end of the new tube in the New Observatory, one of the old eyepieces has been slipped into the



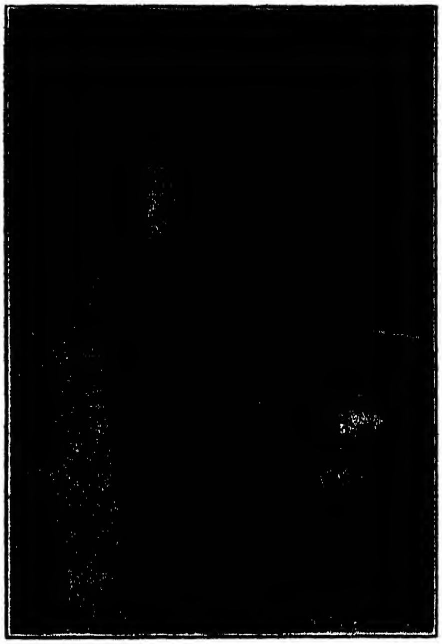
—*Student Photo Service*

THE NEW OBSERVATORY AT PRINCETON

THE LARGE PLATE GLASS WINDOWS GIVE PLENTY OF LIGHT IN THE LABORATORY ROOMS AND THE BROAD SILLS MAKE A GOOD PLACE TO STUDY AND MEASURE PHOTOGRAPHIC PLATES. THE FLAT ROOF IS AN EXCELLENT PLACE FROM WHICH TO STUDY CONSTELLATIONS OR HUNT FOR COMETS. THE HEAVY CASTINGS WERE TAKEN IN THROUGH THE DOUBLE DOORS AND LIFTED WITH THE FLOOR. THE ASTRONOMER RUNS HIS CAR INTO A HEATED GARAGE AND FINDS HIS CAR READY TO START WHEN HE IS READY TO GO HOME. THE ONLY "CHIMNEY" IS A SMALL DARK SPOT HALF WAY UP THE WALL ABOVE THE CORNER OF THE GARAGE DOORS.

small end, thirty feet away, and the telescope is again in commission. The lenses, made by Alvan Clark 50 years ago, are in perfect condition after their half-century of service gathering light from distant stars and concentrating it for study by several generations of astronomers. This speaks well both for the maker and for the astronomers who have periodically washed and dried the lenses with great care and have been constantly on the watch to grab the arm of a visitor who has pulled out his handkerchief and is just going to briskly remove some dust.

While the big lenses and the set of eyepieces of various magnifying powers are the optical essentials of a telescope, the tube which connects them, the machinery by which the tube is quickly moved into position pointing at the star to be observed and by which it follows the motion of the star, the dome which is turned so that the shutter opening is in the right place, the devices to bring the observer to a comfortable position at the eyepiece as the telescope moves are all important matters. All these problems have been ingeniously met by the maker, J. W. Fecker, successor to John A. Brashear.



—*Student Photo Service*

THE BASEMENT MACHINERY

FOR OPERATING THE FLOOR. THE COUNTERWEIGHTS SLIDE DOWN ALONG THE WALL AS THE FLOOR GOES UP. PLIABLE CABLES CARRY THE ELECTRIC WIRES UP TO THE TELESCOPE. THE STEEL COLUMN WHICH CARRIES THE TELESCOPE RESTS ON A MASSIVE CONCRETE BLOCK. ADJUSTING SCREWS ARE PROVIDED SO THAT THE COLUMN CAN BE MOVED TO JUST THE RIGHT POSITION.

—*Student Photo Service*

AN INTERIOR VIEW

THE FLOOR IS AT ITS HIGHEST LEVEL, NEARLY UP TO THE RUNNING GEAR OF THE DOME. THE CONTROL PANEL AND THE SETTING DIALS ATTACHED TO THE RAILING GO UP AND DOWN WITH THE FLOOR. THE SAME CONTROLS ARE BROUGHT DOWN THROUGH THE TELESCOPE AND ARE ALWAYS WITHIN REACH OF THE OBSERVER. THE "FINDER," ON TOP OF THE TUBE, IS ITSELF A VERY RESPECTABLE TELESCOPE WITH A 6-INCH OBJECT-GLASS. THE LOWER END OF THE "POLAR AXIS" CAN BE SEEN, CARRYING THE "HOUR CIRCLE."

The design of the building and its location are perhaps of still greater importance. The New Observatory has been built in a large open area used for polo and artillery maneuvers. The trustees have promised that there will be no encroachment of street or house lights. To get a good dark sky and still keep an observatory accessible to a university is always a problem.

That the observatory may not create a nuisance of its own, a gas furnace, which produces no smoke, was selected for heating the office and laboratory rooms. This heat is kept from the dome by an "air-lock"—an unheated corridor with double doors. The telephones are on the town exchange so that the observer may call for help if he breaks his leg after midnight when the university exchange closes.

As the astronomer enters the dome he unlocks a padlock, throws on the power and turns on the floodlights around the wall of the dome. He gives a few pulls on a rope and the two shutters roll back, leaving an 8-foot opening well beyond the zenith. The telescope is in a horizontal position high above the floor. He goes across to the south end of the pier, starts the "driving clock" which moves the telescope to keep up with the stars, presses a button and the whole floor, forty feet in diameter, starts to rise. The button has to be held down to keep the floor moving so there is no danger of walking off and forgetting it. The astronomer rides up twelve feet, where the power is automatically cut off, takes the caps off the big telescope and the "finder," then presses the "down" button until the floor is low enough to swing the telescope about its two axes into the desired position. A clutch button and another button set the telescope swinging rapidly in declination or in hour angle. Without the clutch buttons and other buttons give slow motions for fine setting. There are large graduated circles on the two axes by which the telescope may be set for the two coordinates of the star to be observed, but also on either side of the control panel carrying all the buttons there is an illuminated dial which, by means of Selsyn motors, synchronizes with the graduated circle and gives the same reading, and the astronomer watches this until the pointer comes to the right reading.

He now presses one of another pair of buttons and the dome rolls round until the telescope is looking out through the opening. An icy wind is blowing over the dome and dropping down the back of the observer's neck. Throwing a switch he pulls a heavy canvas curtain, fastened at intervals to rollers, up from the bottom and another down from the top until the opening is little more than the diameter of the object-glass.

Going to the eye-end of the telescope he looks in the "finder" and finds the star he wants to observe a little to one side of the center. There is a full set of control buttons at his hand here also and with the "slow motions" he centers the star. A table with his record book and pencil and watch is rolled over beside his chair, a faint reading lamp, shielded in a shaving soap box, is plugged in, he shifts the floor until his eye is in comfortable position at the eyepiece and starts to work making measurements and recording them in his book. If the star is too bright for comfortable observing he turns a handle and the iris diaphragm up in front of the object-glass closes up the desired amount. If he is taking a photograph he has slow-slow motion buttons with which to correct any slight irregularities of the driving clock.

There is a slight humming in the Selsyn motors and once an hour a switch closes, a motor starts, and the weight which drives the telescope is wound up. No automobiles, no radio, all is peaceful. The astronomer works on into the night hoping that the bat which hit him in the side of the head one night will not find the new dome.

Raymond S. Dugan

Director of the
Princeton Observatory

KILLCOHOOK MIGRATORY BIRD REFUGE

The first Federal migratory-bird refuge in New Jersey, and also the first in Delaware, was established by executive order of February 3, 1934, by President Roosevelt, on areas acquired by the War Department adjacent to Fort Mott, New Jersey. This, one of the latest of a series of inviolate sanctuaries for wild fowl established under authorization of the Migratory Bird Conservation Act of February 18, 1929, is known as the Killcohook Migratory Bird Refuge and is administered by the Bureau of Biological Survey of the United States Department of Agriculture.

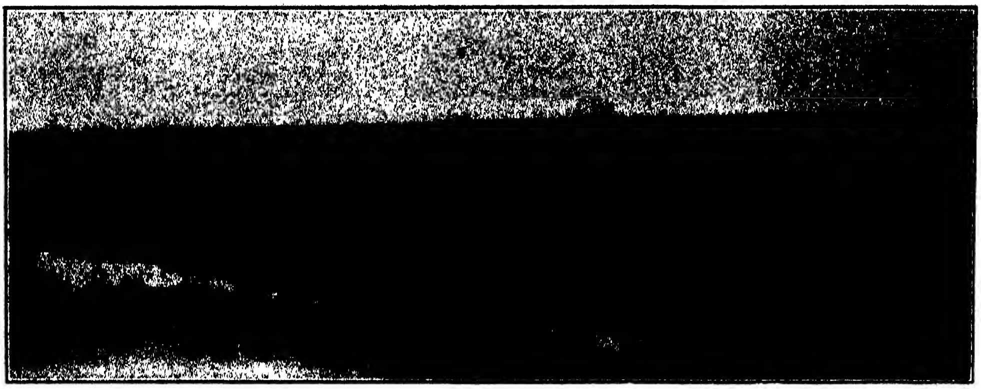
The area of the new refuge embraces approximately 1,440 acres nearly surrounding, but excluding, the Fort Mott Military Reservation and the adjacent Finns Point National Cemetery, both of which are in Salem County, New Jersey. The refuge itself, however, is situated both in Salem County, New Jersey, and in Newcastle County, Delaware. This is by reason of the interstate boundary at this point, which had long been under dispute, and was settled by a decision of the Supreme Court on February 5, two days after the executive order establishing the bird refuge was issued.

Establishment of this refuge resulted from cooperation between the Department of Agriculture and the War Department. The tract embraces areas of land and water acquired by the War Department several years ago to be used as a place to deposit spoil being dredged from the channel of the Delaware River. Though the dredging operations will continue, the area of the refuge is so extensive that it will be attractive to migratory birds for many years.

Most of the refuge consists of water and marshland. Adjoining the marsh area at present is a very large pool of quiet water created by the construction of the Killcohook Dike and the Bulkhead Bar Dike, the former extending down the Delaware River from a jetty light and the other eastward from the light.

THE KILLCOHOOK MIGRATORY BIRD REFUGE

LOOKING WEST TOWARDS THE DELAWARE RIVER, ALONG THE LINE OF THE BULKHEAD BAR DIKE, NEAR FORT MOTT, N. J.



LOOKING ACROSS THE KILLCOHOOK MEADOWS
IN SALEM COUNTY, N. J., NOW PART OF THE FEDERAL BIRD REFUGE OF THE SAME NAME.

Within the limits of this pool, which constitutes nearly one third of the refuge, migratory birds congregate in great numbers, spring and fall.

In addition to offering waterfowl a splendid place to rest and feed, the new refuge is within the breeding range of the black duck. Officials of the Biological Survey anticipate that the area will not only prove to be an important sanctuary for the waterfowl within an extensive region where there are now no refuges, and offer opportunity to rear more ducks than ever before by reason of the protection given, but may become an important outdoor laboratory for scientific investigations for the improvement of conditions in the muskrat industry. Muskrats have been an important source of income to trappers in New Jersey, Delaware, Maryland, and other parts of the United States, and good muskrat marshes are found on the refuge and on large adjacent areas. In fact this region has produced these fur bearers in commercial quantities for more than a century.

The Killcohook Migratory Bird Refuge should also serve to increase public interest in wild-fowl conservation by reason of its ready accessibility and because many motorists every year visit the old breastworks of Fort Mott and the adjacent Finns Point National Cemetery. One attraction to visitors to this old cemetery is a marble shaft 85 feet high, erected by the Federal Government in 1912 to mark the burial mound of 2,436 Confederate soldiers who died while prisoners of war at Fort Delaware, which is just opposite Fort Mott, on Pea Patch Island. The individual graves of these soldiers can not be identified, but the names of each of the 2,436 are perpetuated on 12 bronze tablets on the monument and on the mound surrounding it. This is said to be the largest monument erected by the Federal Government to the memory of the Confederates who died in the North.

The name of the Killcohook Bird Refuge and of the engineering dike and the adjacent meadows is probably of Dutch or Indian origin.

WM. H. CHEESEMAN

INDEX

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